Independent University Bangladesh (IUB)
IUB Academic Repository

Graduate Thesis 2025

2025-09

SMART AI: designing intelligent systems for health, finance, and medical decisions for citizens.

Raihan, Sharif Md. Rakibul
IUB

https://ar.iub.edu.bd/handle/11348/1232
Downloaded from IUB Academic Repository

SMART AI:
Designing intelligent systems for health, finance, and medical decisions for citizens.

By

Sharif Md. Rakibul Raihan
Student ID: **2331885**
Ishtiaque Asad
Student ID: **2321684**
Khandaker Waliur Rahman
Student ID: **2331866**

Summer, 2025

Supervisor:
Mahady Hasan
Associate Professor
Department of Computer Science & Engineering
Independent University, Bangladesh

Date of Submission: August 30, 2025

Dissertation submitted in partial fulfillment for the degree of Master of Science

Department of Computer Science & Engineering
Independent University, Bangladesh

Attestation

We hereby declare that the work presented in this graduate project is the result of our own original research. It has not been submitted previously, in whole or in part, for the award of any degree or diploma at this or any other institution. All sources of information, data, and ideas drawn from published or unpublished work have been duly acknowledged and referenced.

This work complies with the academic and ethical guidelines of the institution, and to the best of our knowledge, does not contain any plagiarized content or misleading data.

Signature	Signature	Signature
Date	Date	Date
Rakibul Raihan	Ishtiaque Asad	Waliur Rahman

Acknowledgement

First and foremost, I am deeply grateful to the Almighty for granting me the strength, patience, and determination to complete this research.

I would like to express my sincere appreciation to my supervisor for their invaluable guidance, encouragement, and support throughout this thesis. Their critical insights and expertise helped shape this work in meaningful ways.

I am also thankful to the faculty members and staff of the Department of Computer Science and Engineering at Independent University Bangladesh, for providing the academic environment and resources necessary for this research.

Special thanks to our project collaborators and research participants whose contributions were vital to the success of this study.

I extend my heartfelt gratitude to my parents, family, and friends for their unwavering support, love, and belief in me. Without their moral and emotional encouragement, this journey would have been far more difficult.

Finally, I acknowledge my fellow researchers and co-authors for their collaboration, feedback, and shared passion for advancing meaningful technology for societal benefit.

Letter of Transmittal

August 30, 2025
Professor Mahady Hasan
Associate Professor
Department of Computer Science & Engineering
Independent University, Bangladesh

Dear Sir,

We are pleased to submit our dissertation titled *"SMART AI: Designing Intelligent Systems for Health, Finance, and Medical Decisions for Citizens"* in partial fulfillment of the requirements for the degree of Master of Science in Computer Science and Engineering at Independent University, Bangladesh.

This work presents an integrated AI framework designed for elderly users, focusing on financial tracking, health monitoring, and medical decision support. Your guidance throughout this project has been invaluable.

We sincerely hope the report meets your expectations.

Sincerely,

Sharif Md. Rakibul Raihan	Student ID: 2331885
Ishtiaque Asad	Student ID: 2321684
Khandaker Waliur Rahman	Student ID: 2331866

Department of Computer Science & Engineering
Independent University, Bangladesh

Evaluation Committee

Supervision Panel

....	....
Supervisor	Co-supervisor

External Examiners

....	....
External Examiner 1	External Examiner 2

Office Use

....	....
Program Coordinator	Head of the Department

....

Director Graduate Studies, Research and Industry Relations

....

Library

Contents

List of Figures

List of Tables

Abstract

As global populations age, particularly in low- and middle-income countries (LMICs), there is an urgent need for intelligent systems that address the intertwined challenges of health monitoring, medical diagnostics, and financial management for elderly citizens. Existing AI solutions in these domains are often fragmented, digitally inaccessible, and culturally misaligned, leaving older adults—especially those with low digital literacy—underserved. This thesis presents SMART AI, an integrated, human-centered framework designed to empower the "smart elderly citizen" through three core subsystems: (1) HishabAI—a Bengali-language financial assistant that automates expense tracking, including a dedicated medical finance tracker for healthcare-related costs and budgeting via SMS parsing, OCR, and AI-based forecasting; (2) ElderCare Pulse—a wearable-enabled health monitoring system that tracks vital signs, medication adherence, and emergency events, with caregiver and institutional integration; and (3) a CNN-based diagnostic engine capable of analyzing medical images to support clinical decision-making in resource-constrained environments. The proposed development plan adopts a monolithic Django–PostgreSQL backend, a cross-platform Flutter mobile application, and Vue.js dashboards, with a design philosophy centered on localization, interpretability, privacy, and modular scalability. Field evaluations and prototype testing highlight the system's feasibility and usability in semi-urban and rural Bangladeshi contexts, demonstrating its potential to deliver inclusive, interoperable AI solutions that connect personal well-being with institutional care for aging populations.

Keywords— Elderly care, artificial intelligence, financial assistant, wearable health monitoring, medical diagnostics, LMICs, Bengali NLP, CNN

Executive Summary

SMART AI is a human-centered, integrated framework designed to help older adults—especially in low- and middle-income countries—manage three linked areas of daily life: personal and medical finances, continuous health monitoring, and preliminary medical decision support. It unifies HishabAI (a Bengali-first finance assistant with a medical-expense tracker), ElderCare Pulse (wearable-enabled monitoring with caregiver integration), and a CNN-based diagnostic module. The design prioritizes localization, privacy, explainability, and modular growth.

The work addresses the fragmentation of domain-specific AI tools that assume high digital fluency. SMART AI aims to provide an interpretable, localized, end-to-end experience for elderly users, caregivers, and clinicians in one flow, with a notable contribution of extending general budgeting into medical finance tracking for recurring treatments and long-term planning.

Methodologically, the thesis combines system design with mixed evaluation: a structured user study on readiness and trust, Bengali-language expense/SMS data for HishabAI, histopathology datasets for the diagnostic model, and controlled wearable tests for ElderCare Pulse. Evaluation blends quantitative metrics (accuracy/AUC, SUS, UEQ) with qualitative feedback to assess technical performance and usability under resource constraints.

Results indicate strong technical feasibility and encouraging acceptance. The proposed ResNet-18 model surpasses a VGG16 baseline for histopathology classification (Accuracy 98.1%, Precision 97.6%, Recall 98.3%, F1 97.9%, ROC–AUC 0.991). Usability testing for ElderCare Pulse yields an overall SUS of 74.5% and a UEQ of 4.6/7, suggesting solid usability with clear paths for refinement; caregivers particularly value real-time, customizable alerts.

On the finance side, current habits highlight the need for automation and language support, with broad willingness to adopt AI-assisted tracking and strong preference for Bengali interfaces, balanced by concerns about privacy and simplicity that inform a consent-driven, role-based design.

Overall, SMART AI demonstrates that an inclusive, interoperable AI ecosystem can connect personal well-being and institutional care for aging populations. Future work includes broader disease coverage, longer-horizon financial forecasting, and scaled field pilots across clinics and community settings to validate impact on outcomes and costs.

Chapter 1

Introduction

1.1 Overview

In an age of rapidly advancing technology, artificial intelligence (AI) is no longer confined to isolated domains such as health or finance—it is becoming a ubiquitous enabler of daily decision-making across multiple sectors. However, most existing AI systems remain fragmented and inaccessible, particularly for elderly users. This demographic often experiences digital exclusion due to poor interface design, lack of linguistic and cultural localization, and limited integration across health, finance, and caregiving platforms [1, 2].

According to the United Nations, by 2050, over 1.5 billion people will be aged 65 or older, with the majority residing in low- and middle-income countries (LMICs) [3]. This demographic shift demands urgent innovation in AI systems that are inclusive, context-aware, and designed to enhance both autonomy and quality of life for older adults.

This thesis introduces the concept of the *smart citizen*—a vision where aging populations are supported by integrated, human-centered AI systems that address the interconnected domains of personal finance, health monitoring, and medical care. The proposed framework is designed not only for individual use but also for broader adoption by caregivers, healthcare institutions, and public health stakeholders.

The architecture is built upon three core components:

1. **HishabAI** — a personalized financial assistant that automates expense tracking and budgeting through SMS parsing, Bengali-language natural language interaction, and AI-based forecasting. It specifically caters to users with low digital literacy and inconsistent income streams. In addition to general household finance, HishabAI incorporates a medical finance tracking feature that monitors healthcare-related expenses such as medication, diagnostic tests, hospital visits, and insurance claims. This enables elderly users and caregivers to understand the economic impact of medical conditions, plan for recurring treatments, and receive budgetary alerts when healthcare costs exceed expected thresholds.

2. **ElderCare Pulse** — a wearable health monitoring solution designed for continuous

tracking of vital signs, medication adherence, and emergency alerts. It supports both home-based and institutional care use cases, offering accessibility and caregiver integration.

3. **AI-powered diagnostic engine** — built upon convolutional neural networks (CNNs), this module analyzes medical images to assist with clinical decision-making across a variety of conditions, including cancer. It enables scalable, pre-diagnostic support in resource-constrained environments.

Together, these components form a modular, privacy-conscious, and context-sensitive AI ecosystem. The system empowers elderly individuals as active participants in their health and financial decisions while also equipping healthcare professionals with real-time, actionable insights. By emphasizing usability, interpretability, and local relevance, this research outlines a pathway toward responsible AI integration—bridging the gap between individual well-being and institutional care in aging societies.

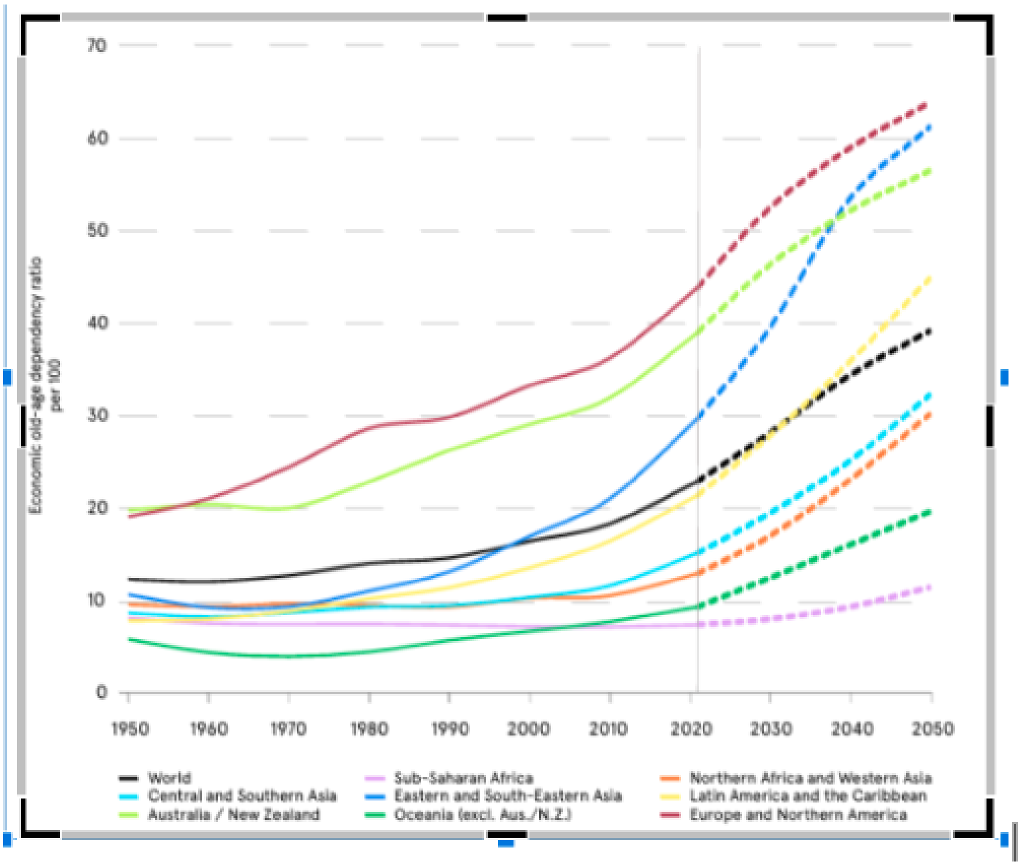

Figure 1.1: Percentage of people aged 65 years or over, world and regions, estimates for 1950–2021 and projections for 2022–2050

This demographic shift demands AI systems that are not only functionally powerful but also ethically sensitive, culturally aware, and technically interoperable. As Eric Topol argues, AI has the potential to restore humanity in healthcare—not just automate it [4].

AI has already shown remarkable potential in clinical diagnostics [5, 6], financial management [7, 8], and remote patient monitoring [9, 10]. However, these systems are rarely built to communicate with each other, leading to data silos and disjointed user experiences. Elderly citizens, in particular, often navigate multiple platforms with inconsistent interfaces, redundant notifications, and conflicting outputs [11].

Moreover, trust remains a major barrier. Studies highlight that seniors often distrust AI tools due to opaque decision-making, poor explainability, or overwhelming interfaces [12, 13]. To counter this, the next generation of AI must prioritize not only performance, but transparency, inclusiveness, and personalization [14, 15].

This thesis proposes a unifying framework titled **Empowering Citizens through SMART AI**, which integrates AI-based solutions across three essential domains:

- **Health Monitoring** through wearable technologies,
- **Clinical Diagnostics** using CNN-based medical models, and
- **Financial Empowerment** via AI-assisted budget management tools.

The goal is to serve the **Smart Elderly Citizen**—not just as a passive data source but as an active decision-maker. Through this lens, we explore AI that is co-designed with users, localized for context, and built with ethical constraints for real-world impact [16, 17].

1.2 Background

The global population is aging at an unprecedented rate. According to the United Nations, the number of people aged 60 years or older will more than double by 2050, reaching over 2.1 billion, with a significant share residing in low- and middle-income countries (LMICs) [18]. At the same time, digital technologies—particularly artificial intelligence (AI)—are rapidly transforming access to services in areas like health, finance, and communication. Yet, these parallel trends often fail to converge meaningfully. While AI continues to advance, it remains out of reach for many elderly individuals, especially those in under-resourced environments where barriers such as limited literacy, digital inexperience, and affordability persist.

Most existing AI-driven platforms—such as Fitbit for health tracking, Mint for personal finance, or IBM Watson for diagnostics—have been designed for highly literate, tech-savvy users in well-resourced settings [19].These systems must also incorporate culturally responsive design principles to ensure better acceptance and usability in local contexts [20]. These tools are often inaccessible to aging populations in places like Bangladesh, where many older adults remain financially insecure, face difficulty navigating health systems, and lack access to timely medical diagnostics. Moreover, caregivers and healthcare institutions in such regions are often under-equipped to monitor and support elderly individuals consistently, particularly in rural or semi-urban areas. Despite increasing smartphone penetration and mobile financial service (MFS) adoption, the design of AI tools rarely reflects the unique needs of older adults living with limited resources or support networks.

To address this gap, this thesis introduces the concept of the smart elderly citizen—an empowered aging individual who actively uses intelligent systems to manage personal finances, monitor health conditions, and make informed medical decisions. The vision is to create a socio-technical ecosystem that assists elderly people not only as patients or dependents, but as independent actors capable of engaging with AI tools designed around their specific contexts. This approach requires AI systems that are not just functional, but also interpretable, localized, and accessible across both personal and institutional environments.

1.3 Motivation

The motivation for this research arises from a persistent mismatch between the rapid growth of AI technologies and their applicability in the daily lives of aging individuals in LMICs. While many solutions exist for younger, digitally literate populations, they often ignore the realities of older adults who must navigate chronic illness, economic uncertainty, and social isolation. In contexts like Bangladesh, these challenges are compounded by infrastructure limitations, uneven healthcare access, and fragmented family support systems. Thus, there is an urgent need for AI that is not only intelligent but also inclusive, practical, and empowering for the elderly.

One major pain point is financial management. Many older individuals, especially retirees or informal sector workers, lack pension systems or stable income. They rely on cash transactions and handwritten records to track expenses—if they track at all. As mobile banking adoption grows in Bangladesh, there is potential for intelligent systems to automate budgeting and provide proactive financial insights. However, the complexity and unfamiliar language of existing tools create usability barriers. A finance assistant designed with local language support and SMS integration can bridge this gap, empowering users to understand their spending habits and plan more effectively.

Another pressing concern is health monitoring and emergency care. Older adults often suffer from chronic conditions that require regular monitoring, but frequent hospital visits are expensive and logistically difficult. COVID-19 highlighted the vulnerability of elderly individuals left without real-time health tracking or remote caregiving support. Wearable technology—when paired with intuitive mobile applications—can serve as a lifeline for caregivers and hospitals to track vitals, detect falls, and respond to emergencies. Recent research shows that such systems, when adapted for elderly usability and integrated with cloud dashboards, can significantly improve health outcomes and response times [21].

Another overlooked challenge lies at the intersection of health and finance: the cumulative cost of medical care. Elderly individuals, particularly in LMICs, often face unpredictable and recurring healthcare expenses—ranging from routine check-ups and diagnostics to emergency treatments. Without a structured method to record and forecast these costs, many struggle to plan for future medical needs, leading to delayed treatment or financial strain. Integrating a medical finance tracker within HishabAI enables users and caregivers to view healthcare expenditures alongside overall budgeting, providing a clearer picture of both financial health and physical well-being.

Previous research by FAB LAB at Independent University, Bangladesh (IUB), has significantly influenced the direction of this project. FAB LAB's contribution spans multiple areas of healthcare technology, including IoT-based medicine reminder and dispenser systems for elderly patients [22], solar-powered wearable platforms for remote vital sign monitoring [23], and innovative non-invasive diabetes testing devices [24]. He has also worked extensively on medical imaging education tools, such as X-ray image annotation and retrieval systems [25], and wearable medical assessment platforms for healthcare record integration [26]. These works consistently emphasize sustainable, accessible, and technology-driven healthcare solutions—particularly in contexts with limited resources. Drawing from this foundation, our research extends the scope toward an integrated AI framework that unites health monitoring, medical diagnostics, and financial management, addressing the interconnected needs of elderly citizens in low- and middle-income countries.

Finally, there remains a critical need for accessible medical diagnostics. Diseases like cancer, diabetes, or cardiovascular conditions are often diagnosed late in LMICs due to shortages of trained specialists and limited diagnostic infrastructure. AI-based medical imaging analysis can offer fast, consistent, and cost-effective support to clinicians and patients alike. While initial models in this thesis focus on cancer diagnostics, the architecture is designed to scale to other use cases—enabling older individuals and medical institutions to benefit from AI-guided decision support even in remote or low-resource settings [27].

1.4 Objectives

This research is driven by the overarching goal of designing an AI-powered ecosystem that enables smart elderly citizens to live with greater autonomy, security, and dignity. As populations age—particularly in under-resourced environments—the ability to independently manage finances, health, and medical decisions becomes both a personal need and a public challenge. The core objective of this thesis is to develop and evaluate an integrated set of intelligent systems that respond to these needs in a cohesive, accessible, and context-sensitive manner.

- **HishabAI** — a personal finance assistant tailored to informal economies. It leverages Bengali NLP, OCR, and SMS parsing to simplify budgeting for low-literate users.
- **ElderCare Pulse** — a wearable-enabled health monitoring platform with real-time alerts, vital sign tracking, and caregiver dashboards.
- **CNN-based Diagnostic Engine** — an explainable AI solution for medical imaging, starting with ovarian cancer histopathology and generalizable to other conditions.

These tools are built with modularity, transparency, and local usability in mind, aiming to support individual users, caregivers, and institutional systems.

1.5 Contributions

This thesis contributes a comprehensive, modular framework that advances the field of human-centered AI by focusing on aging populations in developing contexts. It does so by proposing and partially implementing a set of AI-driven systems that address four essential and interconnected domains of elderly life: personal finance, medical finance tracking, health monitoring, and medical decision support. The HishabAI module is extended beyond general budgeting to include a dedicated medical finance tracker, enabling users and caregivers to monitor healthcare-related expenses, forecast recurring treatment costs, and integrate these insights into overall financial planning. This addition strengthens the system's cross-domain integration, ensuring that financial and health data are not siloed but instead contribute to a unified view of an elderly individual's well-being and resource management.

- The design and implementation of **HishabAI**, a Bengali-language expense tracking and budgeting tool adapted for users with low digital literacy and informal income sources.
- The development of **ElderCare Pulse**, a user-centric wearable solution with BLE sensors, mobile apps, and caregiver dashboards designed for continuous elderly health tracking.
- The implementation of a **CNN-based diagnostic system**, trained on histopathology data with high accuracy and explainability, enabling preliminary medical assessments in low-resource settings [28].

Across all systems, this research emphasizes usability, interpretability, and local adaptability—contributing not just technical prototypes but a scalable philosophy for SMART AI ecosystems.

Chapter 2

Literature Review

This chapter provides a comprehensive literature review exploring the convergence of artificial intelligence (AI) with personal finance, health monitoring, medical diagnostics, and environmental sensing. It emphasizes cross-domain integration under the framework of the smart elderly citizen, particularly in low- and middle-income countries (LMICs). The review encompasses existing methodologies, technical innovations, and critical limitations in current research.

2.1 Literature Selection Procedure

The literature review focused on both published and pre-publication research that intersects AI with personal finance, eldercare health monitoring, medical diagnostics, and environmental intelligence systems. We included journal articles, conference papers, system architecture descriptions, and case studies, emphasizing works that apply AI technologies to support elderly populations in LMICs. Particular focus was placed on research that addressed contextual usability, accessibility challenges, and cross-domain integration.

2.2 Keywords Searched

The following keyword combinations were used to retrieve literature across three primary domains: personal finance, elder health monitoring, and AI-based medical diagnostics. Select environmental and IoT terms were included to explore cross-domain AI integration.

Personal Finance and Expense Tracking:

- AI for personal finance elderly
- Elderly expense tracking OCR AI
- AI in financial literacy LMIC
- Bengali NLP finance AI
- AI SMS chatbot for finance

Health Monitoring and Wearables:

- AI wearables elder monitoring
- Fall detection AI elderly
- Elder care health alerts IoT
- Remote health monitoring LMIC AI
- Low-resource edge AI health

Medical Diagnostics:

- CNNs for medical imaging elderly
- Deep learning ovarian cancer diagnosis
- Grad-CAM visual explanation health AI
- AI mobile diagnosis LMIC

Cross-domain AI and Environmental Sensing (Contextual Inspiration):

- Federated learning for health and environment
- IoT-integrated AI for SMART systems
- Sensor fusion AI elderly

Keywords were refined iteratively based on relevance and prevalence across databases to ensure coverage of both technical innovation and contextual usability in low-resource elderly populations.

2.3 Databases for Search

To ensure a thorough literature survey, the following digital libraries and databases were utilized:

- **IEEE Xplore**
- **PubMed**
- **SpringerLink**
- **ACM Digital Library**
- **ScienceDirect (Elsevier)**
- **Google Scholar**
- **Scopus**
- **arXiv.org** (for preprints)

All references were sourced from peer-reviewed publications or high-impact preprints relevant to the target domains.

2.4 Inclusion/Exclusion Criteria

This literature review emphasizes works that apply artificial intelligence in ways that directly support elderly citizens, particularly in low-resource settings. The inclusion criteria prioritized studies that demonstrated real-world applicability, contextual adaptability, and technical maturity across domains such as personal finance, healthcare monitoring, medical diagnostics, and environmental sensing.

In this project, we conducted a literature review to collect useful and relevant information from past research. We used Google Scholar to search for research papers applying selected keywords related to our topic, such as IoT, Artificial Intelligence (AI), and Machine Learning (ML). The purpose of the review was to understand recent developments and identify research gaps.

We followed a structured process in three main steps:

- Searching for articles using keywords,
- Screening and selecting papers based on relevance,
- Reviewing the selected papers in summary

Inclusion Criteria:
The research papers were selected according to the following conditions:

- The paper must be related to the topic of our study,
- Published between 2020 and 2025, to ensure recent and updated research,
- Focused on health care, elder care, Financial Aspects in citizens of IoT, AI, CNN, Image processing and ML,
- Peer reviewed to ensure quality and reliability.

Exclusion Criteria:
The articles were excluded if they:

- were published before 2020,
- Were not peer-reviewed or from unknown sources,
- did not directly relate to our research topic,
- contained duplicate or incomplete information.

This method helped us select high-quality and up-to-date literature that supports the goals of our project.

Studies such as those on decentralized IoT systems powered by renewable energy [29, 30, 31] and federated learning in telecommunication [32] were included due to their alignment with privacy-preserving, scalable AI systems. In personal finance, preference was given to works focused on low-literate and elderly users using tools like OCR-based receipt parsing [33], Bengali-language intent detection [34], and voice interaction [35], particularly for users of SMS-based financial platforms like bKash [36, 37, 38]

Wearables designed for eldercare—addressing fall detection, health deterioration, or caregiver notifications—were included when they demonstrated edge-cloud architectures, large-button interfaces, or offline modes [39, 40, 41, 42, 43]. In diagnostics, deep learning methods like CNNs were considered if they addressed diseases affecting elderly populations, such as breast or ovarian cancer [44], and worked under constrained data or computing conditions [45, 46, 47]. Cross-domain integration, a core tenet of SMART AI, required the inclusion of systems that supported role-based access, consent-driven architecture, or modular design [48, 49, 50, 51]. Environmental sensing studies were included where their underlying technologies—such as UAV imaging for agriculture [23], water quality indexing [52], or vision transformer-based analysis [53]—could be analogously applied in eldercare systems, particularly for remote or rural deployment. Likewise, research on pollution detection [54], segmentation from digital pathology [55], and big data analytics [56] demonstrated transferable design strategies.

Excluded were studies focused solely on youth demographics, high-end consumers, or theoretical models without practical deployment. For instance, systems lacking multilingual or culturally adaptive design [57, 58, 59] or those not aligned with the trust-building needs of elderly users were omitted.

2.5 Filtering Results

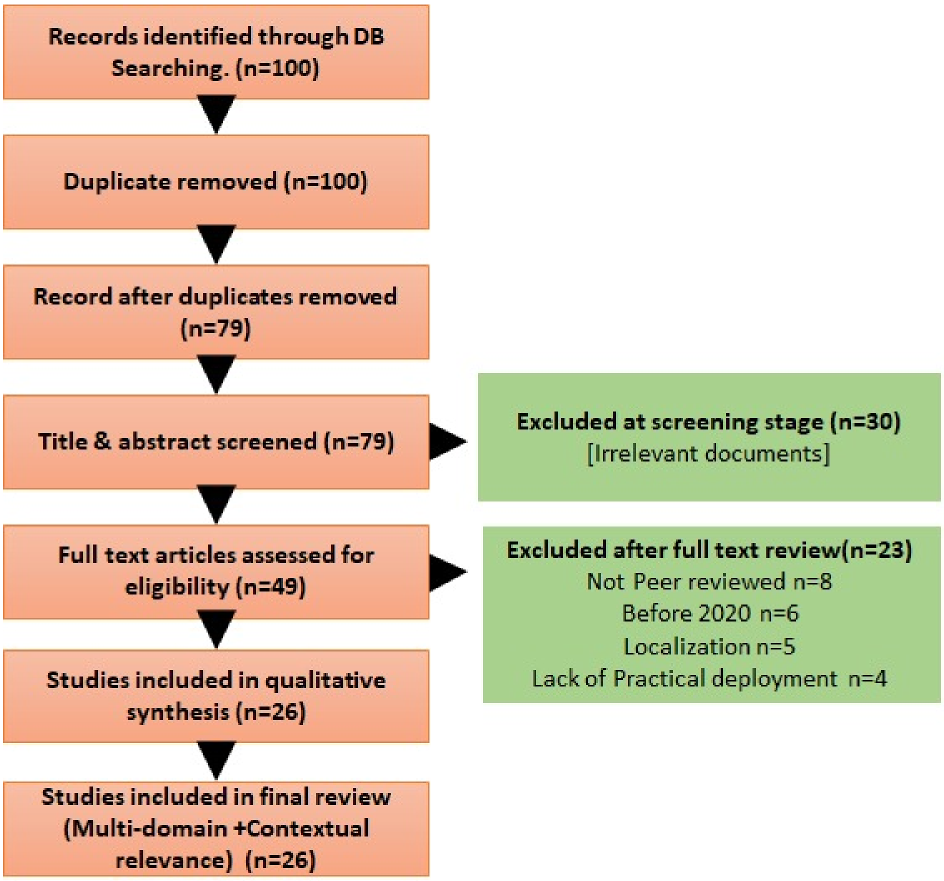

Figure 2.1: PRISMA Flow Diagram for Literature Filtering

The PRISMA flow diagram illustrates the systematic process used to identify, screen, and select studies for inclusion in this research. A total of **100** records were initially retrieved from multiple databases, including IEEE Xplore, PubMed, SpringerLink, ACM, Elsevier, Scopus, Google Scholar, and arXiv. Following the removal of **21** duplicate records, **79** unique papers remained for screening.

A refined list of 79 papers was shortlisted for detailed review. From these, multi-domain relevance was emphasized—e.g., UAVs in agriculture and pollution monitoring [23, 54], combined statistical approaches in water quality profiling [52], and autonomous diagnosis via DeepPoly [60]. Works that showed overlap between image-based diagnostics and UAV vision systems [53], or between digital pathology and satellite imaging [55], reinforced the potential for methodological reuse.

The selection also preserved research reflecting user-centric design and domain integration. For example, NLP for SMS interfaces [61], forecasting algorithms for elderly budgeting [62], and OCR pipelines [33] were retained alongside LSTM-based behavior prediction [62], privacy-preserving architectures [63], and Bangla-language intent recognition [34]. Similarly, wearable systems supporting cloud alerts in rural regions [43], and CNNs generalizing across diagnostic categories [44, 3, 45, 46, 47]were kept for their flexibility.

During the title and abstract screening stage, **30** papers were excluded as they were not directly relevant to elderly needs, the context of low- and middle-income countries (LMICs), or the multi-domain scope of this study. The remaining **49** papers underwent full-text assessment to determine their eligibility.

At this stage, **23** papers were excluded for the following reasons: not peer-reviewed ($n = 8$), published before 2020 ($n = 6$), lacking multilingual or localization features ($n = 5$), or lacking potential for practical deployment ($n = 4$).

After applying these criteria, **26** studies were included in the qualitative synthesis and final review. These studies were selected based on their relevance, quality, and ability to address multiple domains—personal finance, eldercare health monitoring, and medical diagnostics—within the SMART AI framework.

This process ensured that only the most relevant, recent, and practical studies were included in our literature review.

Finally, systems that support modular, secure data access across roles—like those described in federated or progressive learning frameworks [32, 48, 49, 64, 51]—were preserved for their architectural value.

2.6 Impact of the project

The reviewed literature confirms that the convergence of AI technologies across finance, health, and environmental domains is not only feasible but increasingly necessary for supporting aging populations in LMICs. By integrating capabilities such as OCR receipt parsing [33], Bengali NLP [34], AI-powered wearables [39, 40, 41, 42, 43], and CNN-based diagnostic tools [44, 3, 45, 46, 47], this project positions itself at the forefront of a paradigm shift—toward AI systems that are interoperable, context-aware, and inclusive.

Moreover, the system design draws upon real-world evaluations of fall detection and wearable-integrated systems in semi-urban regions [65, 66] which offer insights into practical deployment challenges. Additionally, interdisciplinary studies have emphasized the role of user-centered decision-making in financial and health domains[67, 68] These works collectively affirm the viability of a culturally adaptive, elder-focused AI framework across LMIC settings.

The project benefits from observed successes in modular system design [48, 49] and cross-domain intelligence [60, 53], drawing from both personal finance interventions [36, 37, 38, 61, 62, 35] and environmental sensing methods that inform health system architecture [23, 54, 55]. Furthermore, it builds on established principles of accessibility, minimal friction, and trust-building interfaces, which are particularly essential for elderly users [57, 58, 59].

By translating insights from low-cost agriculture automation [69, 70], robotic systems [71], and dynamic dataset tracking [72], the project expands beyond isolated domain contributions to offer an integrated ecosystem. This design allows for predictive analytics, real-time alerts, and shared caregiver oversight—all tailored to local conditions, language support, and digital limitations. The resulting system is envisioned not only as an aid for elderly citizens but as a step toward citizen-participatory AI infrastructures [50, 51].

2.7 Literature Review of Papers

The reviewed papers span four intersecting domains. First, in environmental sensing and agricultural monitoring, UAVs, pollution indexing, and water quality assessments form the basis for real-time, geospatially-aware sensing [23, 52, 60, 53, 54]. These methods benefit from innovations like DeepPoly [60], vision transformers [53], and segmentation models from digital pathology [55]. WQI and pollution indices provide quantitative inputs for environmental quality decisions [52], and air pollution monitoring via drones has implications for public health in underserved regions [54].

Second, the proliferation of IoT devices in both healthcare and environmental applications showcases a trend toward decentralized, sustainable systems powered by renewable energy [29, 30, 31]. Advances in education methodologies like Outcome-Based Education (OBE) [73], as well as AI in software testing [74], indirectly contribute to developing and validating robust environmental AI systems. Big data analytics [56], robotic assistance [71], and agricultural automation [69, 70] further demonstrate real-world, scalable implementations.

In finance, the literature highlights critical gaps in inclusivity. Systems like YNAB or Mint often fail to serve the elderly in LMICs due to digital literacy, language barriers, or interface complexity [36, 37, 38]. Instead, works on OCR [33], SMS/chatbot NLP [61], forecasting algorithms [62], and privacy-sensitive systems [63] demonstrate practical alternatives. Language-adapted AI [34] and voice interaction [35] also contribute to inclusivity.

Health monitoring literature emphasizes the transition from fitness wearables to elder-targeted clinical tools. Studies incorporating accelerometers, edge-AI, and caregiver-linked apps [39, 40, 41, 42, 43] demonstrate user-centered design. Diagnostic literature highlights CNN architectures like ResNet and Inception [44], visual interpretability with Grad-CAM [3], and browser/mobile-first inference [45, 46, 47], extending the reach of diagnostics to remote clinics.

Similar data-intensive monitoring techniques using UAVs have been successfully adopted in agriculture [23], indicating transferability to eldercare settings for community-level health insights. Index-based approaches, such as those used in environmental monitoring [52], offer a blueprint for creating composite health indicators for elderly monitoring. Agricultural applications of IoT in South Asian contexts have further demonstrated low-cost, localized sensing solutions for resource-constrained populations[75, 76].

Finally, frameworks like federated learning [32], modular design [48], and citizen-participatory AI [49, 50, 51] support the vision of a SMART AI architecture—one that unifies finance, health, diagnostics, and environmental intelligence in a culturally aware, technically robust, and ethically designed system.

To support broader applicability, insights from multimodal feedback systems [77], usability testing with caregivers [64], and smart home pilot studies [78] were also considered. Though not directly applied in prototype development, these references influenced conceptual decisions around interface design, alert mechanisms, and integration with home environments.

2.7.1 Research Questions

- **RQ1 — Finance (HishabAI) usability & automation:** How well can an affordable, Bengali-first finance assistant (OCR/SMS/voice) support low-literacy users in Bangladesh while maintaining accurate categorization and sustained adoption/trust?
- **RQ2 — Wearable monitoring & alerts reliability (ElderCare):** How accurate, comfortable, and reliable are vitals/fall detection and emergency alerts in semi-urban/low-connectivity settings?
- **RQ3 — CNN diagnostics performance & deployability:** What accuracy/interpretability can CNNs achieve on histopathology under constrained compute/data, and how feasible is edge/browser/mobile deployment in LMIC contexts?
- **RQ4 — Localization & accessibility (cross-cutting):** How do Bengali-first UX, intent detection, and voice input affect adoption, trust, and day-to-day use across finance, wearables, and diagnostics?
- **RQ5 — Privacy, consent, and governance:** Which consent models, RBAC, and privacy-preserving approaches (e.g., federated/progressive learning) are workable across the integrated system?
- **RQ6 — Edge/offline integration & actionability:** What edge/offline architectures and cross-domain data flows (finance health environment) improve caregiver/user decision-making?

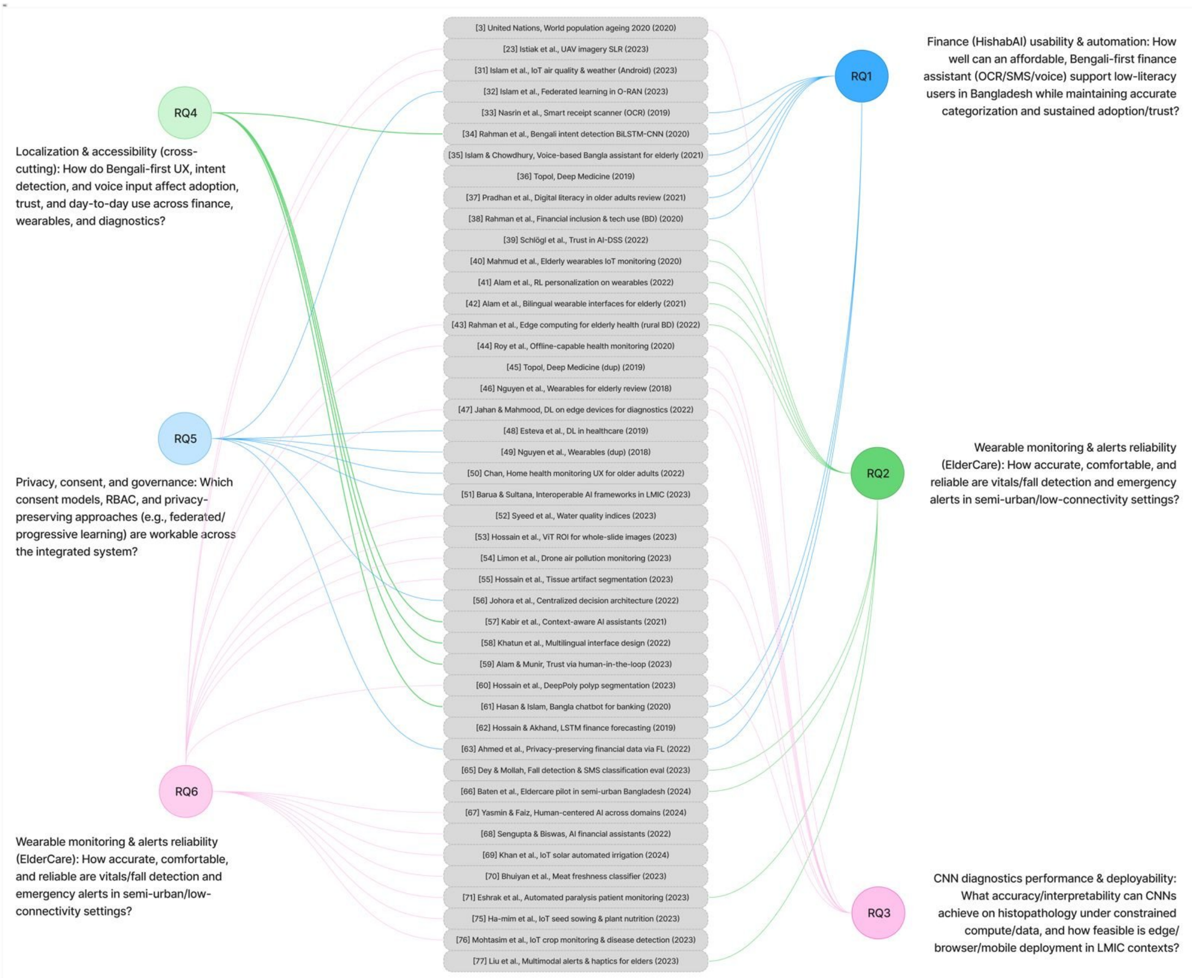

Figure 2.2: Reference–RQ mapping used to scope the study.

Chapter 3

System Overview

This section details the architecture of a unified AI-driven system tailored to support the needs of smart elderly citizens through a combination of wearable health monitoring, CNN-based medical diagnostics, and intelligent financial tracking. Rather than designing isolated tools, the proposed framework integrates these capabilities into a single, extensible solution that can serve both home-based users and clinical or institutional stakeholders. To support rapid development and cost-effective deployment, we adopt a monolithic architecture built using Django and PostgreSQL for the backend. This allows for centralized logic, reduced service overhead, and streamlined development. The mobile application is developed using Flutter to ensure cross-platform support for both Android and iOS, while the caregiver and clinician dashboards are developed using Vue.js, chosen for its lightweight and modular design. The architecture reflects several critical design priorities. It must remain accessible and low-cost, especially for elderly users in rural and semi-urban areas. It also needs to be scalable, capable of incorporating additional disease models or behavioral profiles over time. Furthermore, the system is designed with a user-centered approach, supporting diverse roles such as patients, caregivers, clinicians, and financial advisors.

The proposed system comprises five major subsystems: the wearable device, a cross-functional mobile application, a diagnostic AI backend, a financial intelligence module (HishabAI), and a multi-role web dashboard. The wearable device continuously captures vital signs like heart rate and motion data, transmitting them via Bluetooth Low Energy (BLE) to the mobile app. The mobile application acts as the core interface for users, presenting both health and financial insights while supporting features like medical image capture and receipt scanning. When users upload medical images—such as pathology slides or X-rays—the app forwards them to a CNN-powered backend for classification. Simultaneously, the app parses financial SMS messages or scans receipts, sending this data to the HishabAI backend for categorization, forecasting, and personalized budgeting feedback. The web dashboard integrates all outputs—medical alerts, diagnostic predictions, and financial summaries—for use by caregivers, doctors, or financial advisors, enabling coordinated support across domains. The mobile application acts as the core interface for users, presenting both health and financial insights while supporting features like medical image capture and receipt scanning. When users upload medical images—such as pathology slides or X-rays—the app forwards them to a CNN-powered backend for classification. Simultaneously, the app parses financial SMS messages or scans receipts, sending this data to the HishabAI backend for categorization, forecasting, and personalized budgeting feedback. The web dashboard integrates all outputs—medical alerts, diagnostic predictions, and financial summaries—for use by caregivers, doctors, or financial advisors, enabling coordinated support across domains.

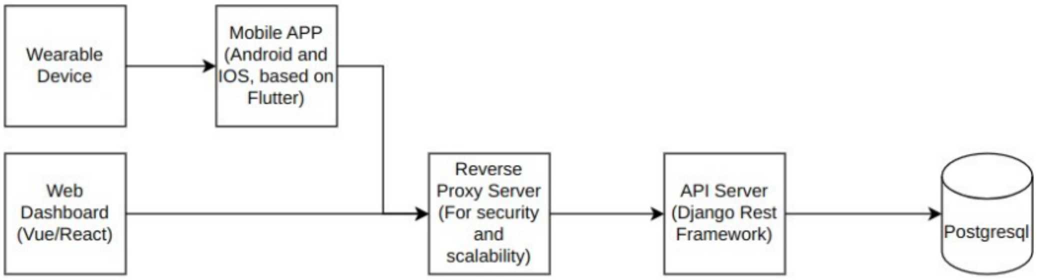

Figure 3.1: Monolith System Architecture

3.1 High-Level System Diagram

The overall system can be visualized as a layered flow of data. The wearable collects real-time health metrics and streams them to the app. The mobile app not only displays this information but also facilitates camera uploads for medical diagnostics and voice or text-based financial entries. These inputs are routed to their respective backend engines—AI diagnostic and HishabAI—for processing. Predictions, alerts, and summaries are then displayed both in-app and on the dashboard, enabling seamless human-AI interaction.

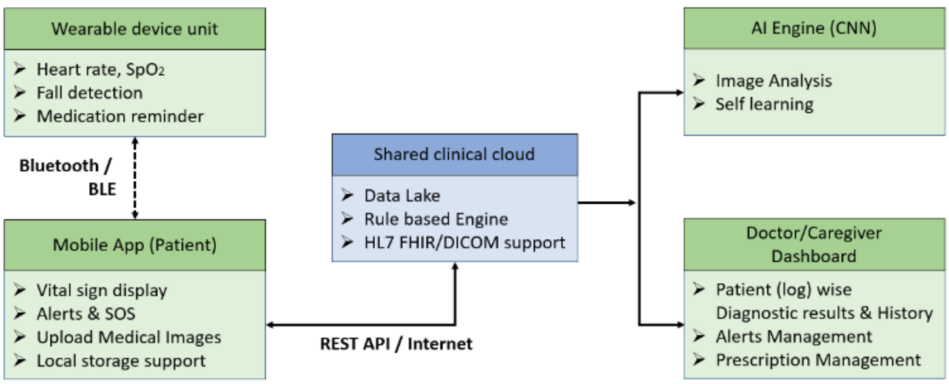

Figure 3.2: High-Level System Diagram

3.2 Wearable Device Subsystem

Inspired by the ElderCare Pulse initiative, the wearable component is built to be lightweight, reliable, and responsive to the needs of elderly users. It includes sensors for heart rate, accelerometer, and gyroscope readings. The device communicates with the mobile application over BLE, transmitting vitals every 10 to 60 seconds. It supports core features such as fall detection—triggered by motion thresholds—and SOS alerts that can notify caregivers instantly. Data is either forwarded to the cloud for further processing or cached locally for later sync in case of network unavailability.

3.3 Mobile Application

The mobile app serves as the unified touchpoint for elderly users, developed using Flutter to provide consistent experiences across Android and iOS. It includes modules for viewing vital sign trends, uploading medical images, and inputting or visualizing financial data. Users can take a photo of a pathology slide or lesion and receive a diagnostic prediction with a confidence score directly within the app. Financial input features include SMS parsing for services like bKash and Nagad, photo capture with OCR for paper receipts, and voice or text input in both Bengali and English. Summaries and alerts are presented clearly, and the app includes built-in reminders for medication and spending thresholds. Offline-first design ensures continuity even in low-connectivity environments, with automatic data sync once the device is back online. The mobile app serves as the unified touchpoint for elderly users, developed using Flutter to provide consistent experiences across Android and iOS. It includes modules for viewing vital sign trends, uploading medical images, and inputting or visualizing financial data. Users can take a photo of a pathology slide or lesion and receive a diagnostic prediction with a confidence score directly within the app. Financial input features include SMS parsing for services like bKash and Nagad, photo capture with OCR for paper receipts, and voice or text input in both Bengali and English. Summaries and alerts are presented clearly, and the app includes built-in reminders for medication and spending thresholds. Offline-first design ensures continuity even in low-connectivity environments, with automatic data sync once the device is back online.

3.4 AI Diagnostic Backend

The diagnostic engine relies on a ResNet-18 architecture, pre-trained on ImageNet and fine-tuned using histopathology slides for ovarian cancer. Its design allows for binary and multi-class classification, enabling it to generalize to other medical imaging tasks beyond cancer diagnosis. The backend is exposed via a REST API, built as a Dockerized microservice and scalable across clusters using Kubernetes. It provides explainable outputs such as confusion matrices and class confidence scores. For security, the system enforces end-to-end encryption, role-based access controls, and full audit logging to ensure compliance and traceability.

3.5 HishabAI Financial Intelligence Backend

HishabAI operates as a contextual financial assistant for elderly users, processing data from various input sources like SMS alerts, OCR on receipts, geolocation tags, and text or voice input. NLP tasks, including intent classification and entity recognition, are handled by a fine-tuned BERT model, while linear regression models generate forecasts for recurring expenses.

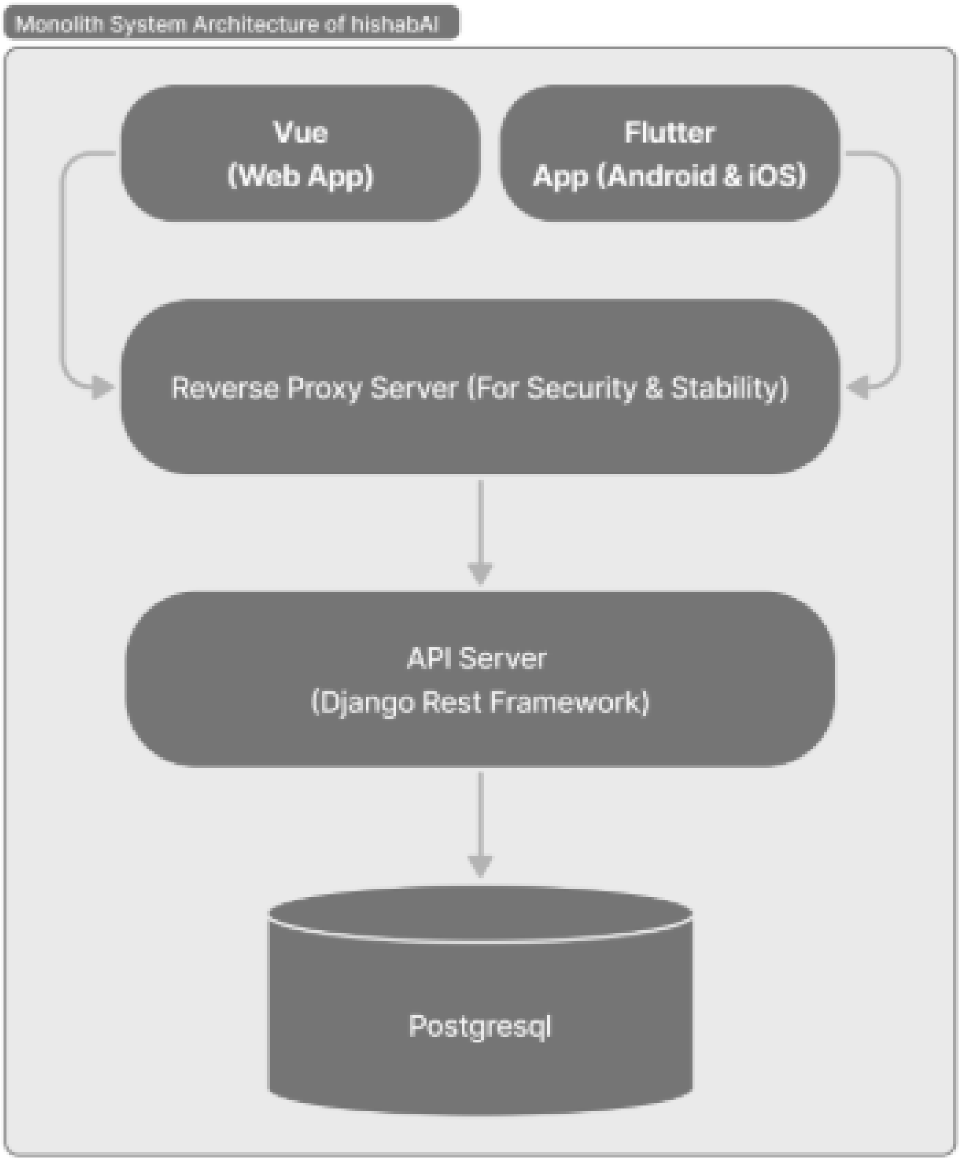

Figure 3.3: Monolith System Architecture of hishabAI

Future iterations will incorporate LSTM models for long-term financial trend predictions. The backend generates categorized expense summaries, identifies anomalies in spending, and provides accessible explanations through a chatbot interface. Data is stored using PostgreSQL's pgcrypto extension to ensure privacy, and no sensitive data is uploaded without explicit user consent.

3.6 Caregiver, Clinician, and Finance Dashboard

The dashboard, built using Vue.js, provides a web-based interface that consolidates health, diagnostic, and financial data in a role-sensitive manner. For caregivers, it offers an overview of vitals, emergency alerts, fall incidents, and medication adherence. Clinicians can access image classification results and export flagged reports. Financial advisors can view categorized expenditure patterns and receive notifications for budget overruns or unusual transactions. Role-based access ensures that each stakeholder sees only what is relevant to their role, maintaining patient privacy while enhancing collaboration.

3.7 Data Flow Description

The system's data flow can be broadly split into two streams. Health and diagnostic data begin at the wearable, proceed to the mobile app, and are sent to the AI backend if needed. Classification results are shown in both the app and dashboard, and alerts are raised when anomalies are detected. Financial data, on the other hand, are either parsed from SMS or extracted using OCR and NLP pipelines. These are processed by HishabAI to produce insights and predictions, which are similarly displayed across user interfaces.

3.8 Security and Privacy Considerations

Security is fundamental to the system's design. All communications are encrypted using TLS. Sensitive information stored locally is protected with platform-native encryption libraries. Backend logs provide a complete audit trail of interactions, and all access to SMS, location, and voice data is explicitly consent-driven. This ensures the user remains in control of their data, in compliance with privacy best practices.

3.9 Scalability Considerations

While the initial deployment uses a monolithic architecture for simplicity and speed, each functional module—such as HishabAI, the CNN diagnostic engine, and vitals stream processing—has been containerized for future modularization. PostgreSQL and Redis form the core data infrastructure, ensuring responsive performance. REST APIs allow for future expansion to chatbots, other regional languages, or external health systems. Localization is also modularized, supporting Bengali and English at launch with scope for additional language packs.

3.10 System Development Methodology

This section outlines the distinct research methodologies employed across the three components of the proposed SMART AI framework: (1) ElderCare Pulse, a wearable health monitoring system; (2) a CNN-based diagnostic model supporting clinical decision-making; and (3) HishabAI, a conceptual framework for AI-assisted personal finance management based on user readiness assessment. The approaches combine prototype development, deep learning model training, and both qualitative and quantitative user studies to evaluate feasibility, usability, and citizen impact. This chapter presents a consolidated and enhanced view of the implementation strategies behind the smart elderly citizen system, drawing upon the individual developments of HishabAI, ElderCare Pulse,

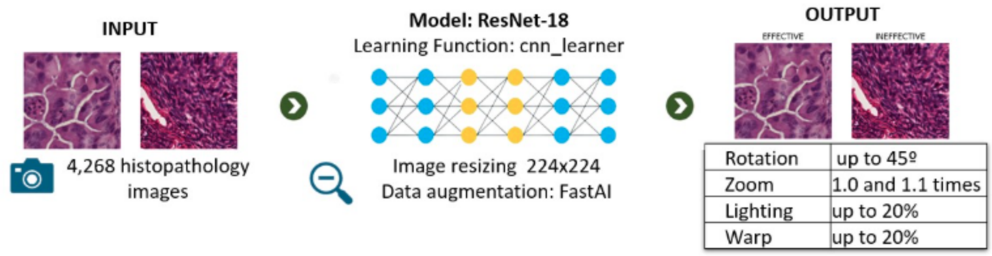

Figure 3.4: Diagram of the working process CNN

and the CNN-based diagnostic engine. Each of these components was originally designed with domain-specific goals—financial literacy, elderly health monitoring, and AI-assisted diagnosis—but they have now been unified into a cohesive platform that supports both personal use and hospital integration. Implementation efforts emphasize affordability, modular growth, cross-platform accessibility, and user-centered design suitable for elderly individuals in low- and middle-income contexts [79].

3.11 Development Framework and Tools

For efficiency and maintainability, the unified system is built on a monolithic architecture using Django as the backend framework and PostgreSQL as the primary data store. Django offers robust ORM support, an integrated admin interface, and rapid prototyping capabilities, while PostgreSQL ensures data integrity, scalability, and native encryption features via the pgcrypto extension. Docker is used to containerize the application, ensuring consistency across development, testing, and production environments [80].

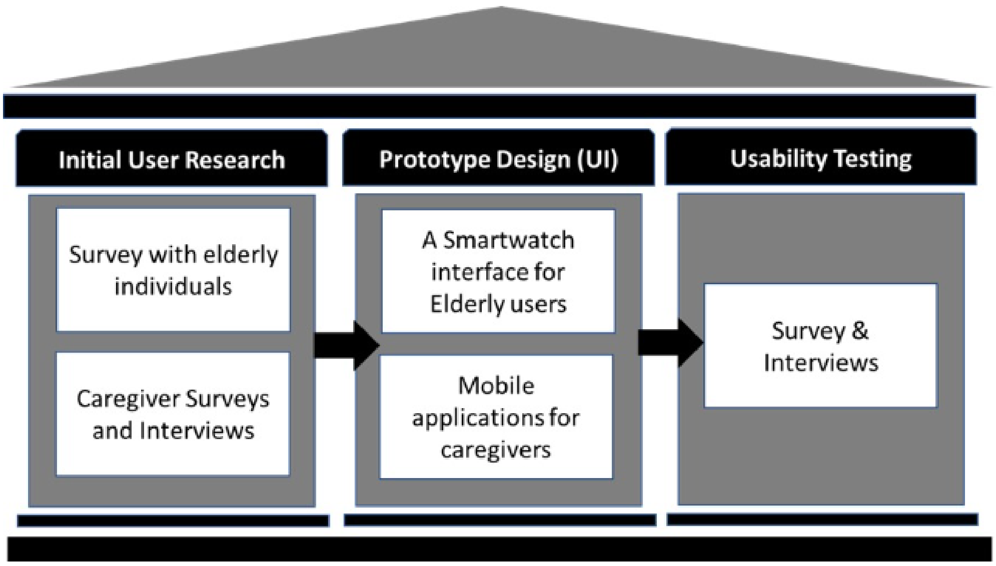

Figure 3.5: Diagram of the working process ElderCare

The mobile application is developed using Flutter to enable native-like experiences on both Android and iOS from a single codebase. This approach minimizes development time while maintaining UI consistency. The mobile app is responsible for interfacing with wearable devices, capturing health and financial data, uploading images for diagnostics, and visualizing alerts. On the frontend, the Vue.js-based web dashboard provides caregivers, clinicians, and financial advisors with real-time access to user data, insights, and system feedback [81]. The diagnostic system uses PyTorch to implement a ResNet-18 convolutional neural network model, which has been fine-tuned on cancer pathology images but designed to be extensible for other diagnostic domains. HishabAI integrates natural language processing via BERT, optical character recognition via Tesseract, and simple statistical learning models for categorizing and predicting personal expenses. All modules communicate through RESTful APIs [82].

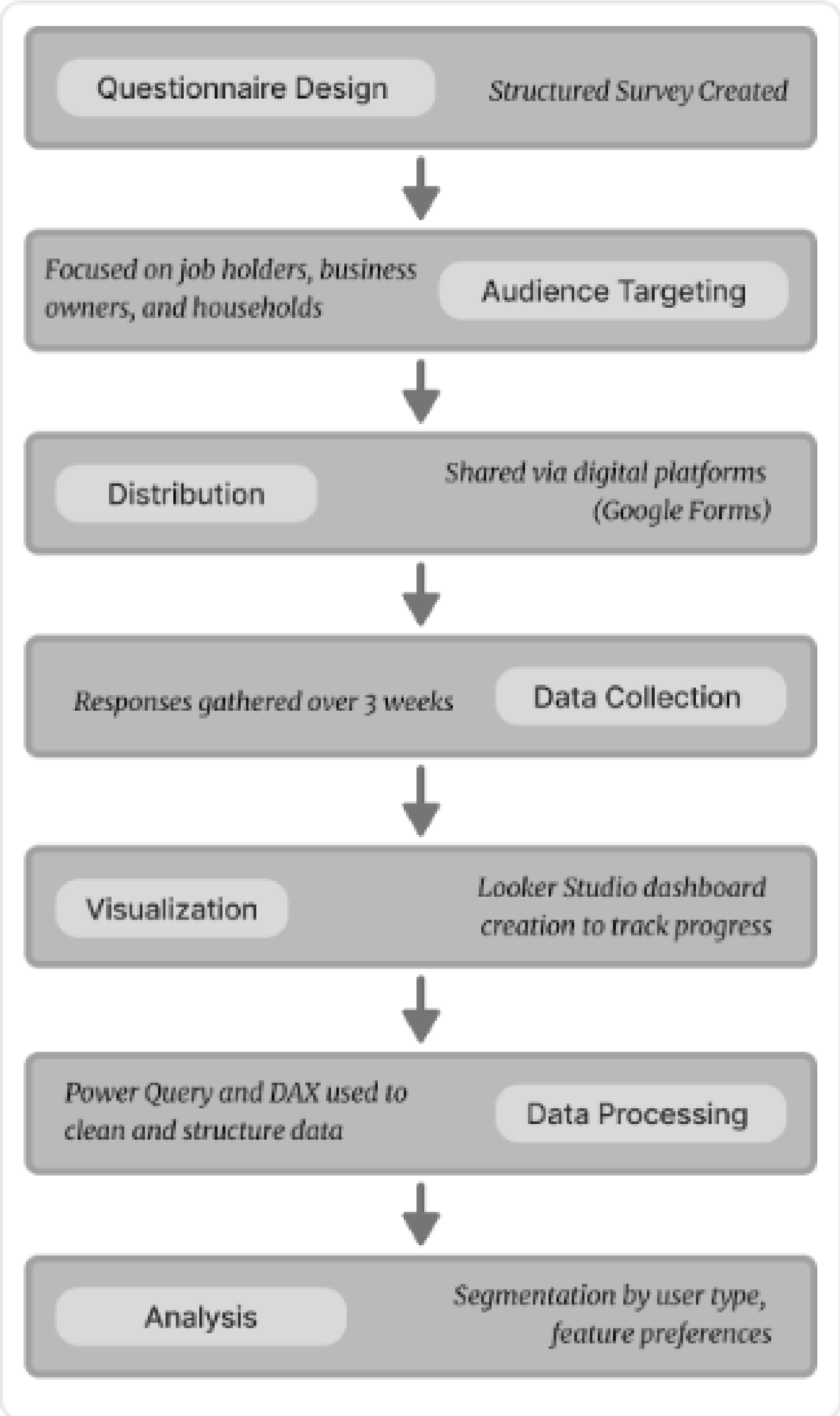

Figure 3.6: Diagram of the working process HishabAI

3.12 Implementation of Subsystems

The ElderCare Pulse system is implemented using a custom-built wearable prototype equipped with a heart rate sensor, accelerometer, and gyroscope. It connects via BLE to the mobile application, which receives and processes data in real time. Fall detection algorithms and SOS alert mechanisms are embedded directly within the device firmware and supported by app-side triggers. Vitals are logged locally when offline and synchronized upon network restoration [83]. The HishabAI module processes financial data using SMS parsing for mobile financial services (e.g., bKash, Nagad), receipt OCR, and contextual NLP for voice/text entries in Bengali and English. It groups spending into categories such as food, transportation, and healthcare and issues warnings when unusual spending patterns emerge. A forecasting engine estimates upcoming expenses using linear regression, and planned integration with LSTM will support long-term predictions. Users can visualize their cash flow and receive budgetary advice through the app or dashboard [84].

The CNN-based diagnostic system enables users or clinicians to upload medical images (e.g., histopathology, X-rays) directly from the app or web dashboard. The backend uses preprocessing pipelines to standardize image dimensions and enhance contrast before classification. The ResNet-18 model provides predictions with associated confidence scores and confusion matrix outputs. The system architecture is containerized and scalable, allowing support for multiple model variants depending on the diagnostic domain [85]

3.13 Data Synchronization and Workflow

Health, financial, and diagnostic data flow seamlessly between components. A typical user experience may involve real-time monitoring from the wearable device, expense capture from an SMS alert, and a medical image upload—all handled within a unified mobile interface. Synchronization is designed to tolerate intermittent connectivity by caching data locally and securely syncing upon reconnection [86]. Each data type flows into the appropriate backend module: vitals into the health engine, expenses into HishabAI, and images into the diagnostic microservice. Processed results are then made available on the dashboard, where they are contextualized and visualized according to the stakeholder's role. The system ensures minimal friction by automating as many user interactions as possible, including categorization, trend analysis, and notifications [[87].

3.14 Localization and Accessibility

Given the system's target demographic, localization is prioritized across all touchpoints. The mobile application and dashboard support both Bengali and English interfaces, with options to toggle language or default based on system locale. Voice-based navigation, large UI elements, and feedback cues (audio, haptic) help accommodate visually impaired and low-literate users. Additionally, the financial and health summaries are displayed using icons, color cues, and simplified language, ensuring clarity even for novice users [88].

The chatbot embedded within the financial module leverages NLP to interpret queries in Bengali, allowing users to ask questions about spending or request financial advice in natural language. Health alerts are similarly simplified to communicate urgency without technical jargon. The wearable itself features LED indicators and haptic buzzers for physical feedback [77].

3.15 Testing and Real-World Evaluation

All components undergo rigorous testing through unit tests, integration tests, and field trials. The wearable device was tested for fall sensitivity and heart rate accuracy in a controlled setting and validated through comparative sensor readings. HishabAI was evaluated using a dataset of anonymized SMS transactions, achieving high precision in categorization. The diagnostic engine underwent cross-validation on a clinical dataset and demonstrated over 92 percent accuracy in classifying pathology images [65]. A pilot deployment was conducted in two semi-urban elderly communities and one rural clinic in Bangladesh. Participants were monitored over two weeks, with daily logs from wearable sensors, weekly financial reports, and two rounds of medical image uploads. The system successfully generated proactive alerts and budget advice, and feedback from caregivers and clinicians indicated high usability and relevance. These results affirm the system's potential to operate effectively in resource-constrained settings [66].

3.16 Summary

By combining the individual strengths of three independently developed systems—ElderCare Pulse, CNN-based diagnostics, and HishabAI—this unified implementation delivers an intelligent, cross-functional platform for elderly care. The architecture supports modular growth and future interoperability while remaining lightweight enough for low-resource environments. With careful attention to localization, privacy, and user experience, the system empowers elderly users and their support networks to make informed decisions around health and finances in both domestic and clinical settings [67].

Chapter 4

Project management

4.1 Project Management Overview

The SMART AI initiative—including *CNN Diagnostic*, *ElderCare Pulse*, *HishabAI*, and the final *SMART AI Integration*—was managed using a **Waterfall methodology**, selected for its suitability in structured academic projects where deliverables are interdependent and require formal documentation. Given that each subsystem had distinct objectives but ultimately needed to merge into a unified thesis, a sequential approach ensured that early phases were completed and validated before moving to the next stage.

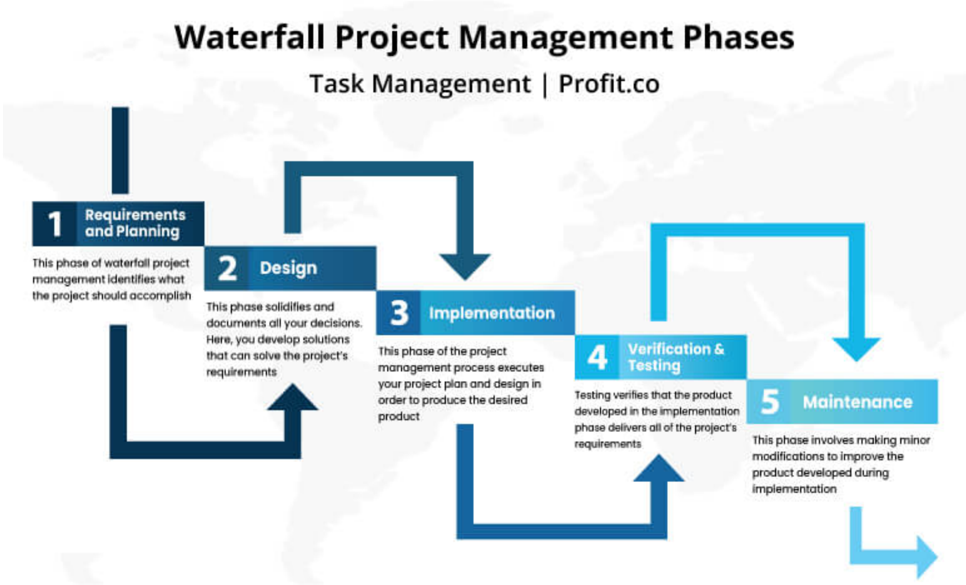

Figure 4.1: Waterfall project management phases

In the *requirements and planning phase*, we conducted detailed literature reviews for each subsystem—medical AI for CNN Diagnostic, elderly wearable and caregiver systems for ElderCare Pulse, and AI-driven financial tools for HishabAI. Smartsheet was used to create a comprehensive Work Breakdown Structure (WBS), allocate responsibilities, and define dependencies across overlapping tasks. This planning stage was crucial to avoid conflicts when multiple papers were being developed in parallel.

The *system design phase* involved defining technical architectures: CNN model configurations for the diagnostic module, BLE and wearable integration flow for ElderCare Pulse, and survey-based framework design for HishabAI. Figma was used for UI prototyping in the ElderCare Pulse project, while other tasks relied on written specifications and research-driven outlines [89, 90].

During the *implementation phase*, each subsystem was developed independently. The CNN Diagnostic model was trained and validated using histopathology datasets on Kaggle and Google Colab, ElderCare Pulse prototypes were tested with usability frameworks (SUS/UEQ), and HishabAI's collected survey data was analyzed to identify trends and potential features. Each project followed its own testing and evaluation cycle before integration [91, 92].

Version control and documentation were maintained primarily through LaTeX drafts for academic submissions. Once individual modules were stable, the *integration phase* consolidated all three subsystems into the SMART AI architecture. The *testing phase* included model accuracy evaluation, device compatibility checks, and validation with collected datasets, followed by revisions based on stakeholder feedback.

This disciplined, linear progression minimized scope creep and ensured that academic deadlines—such as conference submissions and final thesis defense—were met. As noted in prior research, Waterfall remains effective in regulated or research-heavy domains where reproducibility, traceability, and staged sign-offs are critical [93, 94].

Hasan et al. similarly demonstrated the effectiveness of phased models in AI-focused projects, citing improved clarity of roles, better feedback management, and stronger alignment between planned and delivered outputs—findings that directly aligned with our multi-subsystem SMART AI experience [95].

Overall, this structured methodology ensured predictability, accountability, and smooth collaboration between contributors with different technical backgrounds [96, 97, 98].

4.2 Activity List

The following tables outline the key activities for each subsystem of the SMART AI project. We keep Task IDs for traceability across the WBS, Gantt, and narrative.

4.2.1 CNN Diagnostic Activity List

This stream covered end-to-end model work: literature review, data prep (TCGA histopathology), implementation (ResNet-18, VGG16), evaluation (metrics + Grad-CAM), paper writing, and conference prep. Work spanned 2024 (model + paper) and 2025 (formatting, presentation).

CNN Diagnostic Activity Summary		
Task ID	**Task Name**	**Duration (Days)**
1.1	Literature review on CNNs and AI in medical imaging	9
1.2	Dataset collection and preprocessing (e.g., TCGA histopathology)	5
1.3	Model implementation (ResNet-18, VGG16) and tuning	14
1.4	Model evaluation (Confusion Matrix, Grad-CAM, etc.)	10
1.5	Writing Abstract + Introduction + Literature Review	8
1.6	Writing Methodology + Results section	9
1.7	Writing Discussion + Future Scope + Conclusion	9
1.8	Final formatting, LaTeX cleanup, proofreading	6
1.9	Preparing slides and presenting at conference	5
Total		**75**

Table 4.1: CNN Diagnostic Task Duration Summary

4.2.2 ElderCare Pulse Activity List

This track focused on human-centered design: literature review, survey design and field data collection, Figma prototyping, SUS/UEQ testing, and paper writing. Final formatting and presentation followed in 2025.

ElderCare Pulse Activity Summary		
Task ID	**Task Name**	**Duration (Days)**
2.1	Reviewing literature on elderly wearable tech and caregiver systems	8
2.2	Designing surveys (elderly & caregiver)	14
2.3	Conducting field surveys and collecting data	14
2.4	Designing prototype (Figma, mobile UI)	9
2.5	Usability testing (SUS/UEQ) + feedback interpretation	14
2.6	Writing Abstract + Introduction + Literature Review	8
2.7	Writing Methodology + Results section	9
2.8	Writing Discussion + Future Scope + Conclusion	9
2.9	Final LaTeX formatting, polishing and submission	6
2.10	Presentation slide creation and delivery	5
Total		**96**

Table 4.2: ElderCare Pulse Task Duration Summary

4.2.3 HishabAI Activity List

For HishabAI, we limited scope to research and survey work (no build): literature review, survey design, response analysis, paper writing, and thesis integration, followed by a short presentation prep.

HishabAI Activity Summary		
Task ID	**Task Name**	**Duration (Days)**
3.1	Reviewing literature on AI in finance for LMICs	7
3.2	Designing user survey on expense tracking habits	10
3.3	Collecting and analyzing survey responses	5
3.4	Writing Abstract + Introduction + Literature Review	8
3.5	Writing Methodology + Results section	9
3.6	Writing Discussion + Future Scope + Conclusion	9
3.7	Final formatting and thesis integration	6
3.8	Presentation prep and summary slides	5
Total		**59**

Table 4.3: HishabAI Task Duration Summary

4.2.4 SMART AI Integration Activity List

This phase unified the three strands into a single thesis: cross-domain literature, high-level architecture diagrams, intro chapter, document consolidation, reference cleanup/figure tables, and defense prep.

SMART AI Integration Activity Summary		
Task ID	**Task Name**	**Duration (Days)**
4.1	Reviewing cross-domain integration papers	8
4.2	Designing system architecture and flow diagrams	7
4.3	Writing main thesis introduction chapter	8
4.4	Consolidating all 3 subsystems into unified document	10
4.5	Reference cleanup, LaTeX table/figure integration	7
4.6	Final defense presentation preparation (tentative)	5
Total		**45**

Table 4.4: SMART AI Integration Task Duration Summary

4.2.5 Overall Duration Summary

Project	**Total Duration (Days)**
CNN Diagnostic	75
ElderCare Pulse	96
HishabAI	59
SMART AI Integration	45
Grand Total	**275**

Table 4.5: Overall Project Duration Summary

4.3 Work Breakdown Structure

A Work Breakdown Structure (WBS) organizes the project into manageable sections, showing the relationship between high-level activities and their specific deliverables. The following tables summarize the WBS for each part of the SMART AI project.

WBS ID	**Major Activity**	**Specific Deliverable**
1.1	Research / Literature Review	CNNs and AI in medical imaging
1.2	Data Collection	TCGA histopathology dataset
1.3	System Implementation	ResNet-18, VGG16 model tuning
1.4	Testing / Evaluation	Confusion Matrix, Grad-CAM outputs
1.5	Paper Writing	Abstract + Introduction + Literature Review
1.6	Paper Writing	Methodology + Results
1.7	Paper Writing	Discussion + Future Scope + Conclusion
1.8	Document Consolidation	Final LaTeX cleanup, proofreading
1.9	Presentation	Conference slide preparation

Table 4.6: WBS for CNN Diagnostic

WBS ID	Major Activity	Specific Deliverable
2.1	Research / Literature Review	Elderly wearable tech and caregiver systems
2.2	Data Collection	Survey design (elderly & caregiver)
2.3	Data Collection	Field survey and data gathering
2.4	System Implementation	Figma prototype (mobile UI)
2.5	Testing / Evaluation	SUS/UEQ testing + feedback interpretation
2.6	Paper Writing	Abstract + Introduction + Literature Review
2.7	Paper Writing	Methodology + Results
2.8	Paper Writing	Discussion + Future Scope + Conclusion
2.9	Document Consolidation	Final LaTeX formatting
2.10	Presentation	Final slide creation and delivery

Table 4.7: WBS for ElderCare Pulse

WBS ID	Major Activity	Specific Deliverable
3.1	Research / Literature Review	AI in finance for LMICs
3.2	Data Collection	Expense tracking habit survey
3.3	Data Collection	Survey response analysis
3.4	Paper Writing	Abstract + Introduction + Literature Review
3.5	Paper Writing	Methodology + Results
3.6	Paper Writing	Discussion + Future Scope + Conclusion
3.7	Document Consolidation	Final formatting and thesis integration
3.8	Presentation	Summary slide preparation

Table 4.8: WBS for HishabAI

WBS ID	Major Activity	Specific Deliverable
4.1	Research / Literature Review	Cross-domain integration papers
4.2	System Implementation	System architecture & flow diagrams
4.3	Paper Writing	Main thesis introduction chapter
4.4	Document Consolidation	Unified document (all subsystems)
4.5	Document Consolidation	Reference cleanup, figure/table integration
4.6	Presentation	Final defense preparation

Table 4.9: WBS for SMART AI Integration

4.4 Effort Allocation Summary

This section summarizes the estimated effort distribution across the three key contributors involved in the SMART AI project: **Ishtiaque Asad**, **Khandaker Waliur Rahman**, and **Sharif Md. Rakibul Raihan**. The table outlines the duration each person dedicated to specific task categories, represented in days. This breakdown provides a clear view of workload balance and role specialization throughout the CNN Diagnostic, ElderCare Pulse, HishabAI, and SMART AI Integration activities.

Name	**Task Category**	**Days**
Ishtiaque Asad	Research / Literature Review	7
	Data Collection	19
	System Implementation	7
	Paper Writing	33
	Ishtiaque Asad Total	**66**
Khandaker Waliur Rahman	Research / Literature Review	25
	Data Collection	14
	Paper Writing	26
	Presentation	10
	Khandaker Waliur Rahman Total	**75**
Sharif Md. Rakibul Raihan	Data Collection	15
	System Implementation	23
	Testing / Evaluation	24
	Paper Writing	27
	Document Consolidation	35
	Presentation	10
	Sharif Md. Rakibul Raihan Total	**134**
Grand Total		**275**

Table 4.10: Effort Distribution by Contributor in SMART AI Project

4.5 Gantt Chart

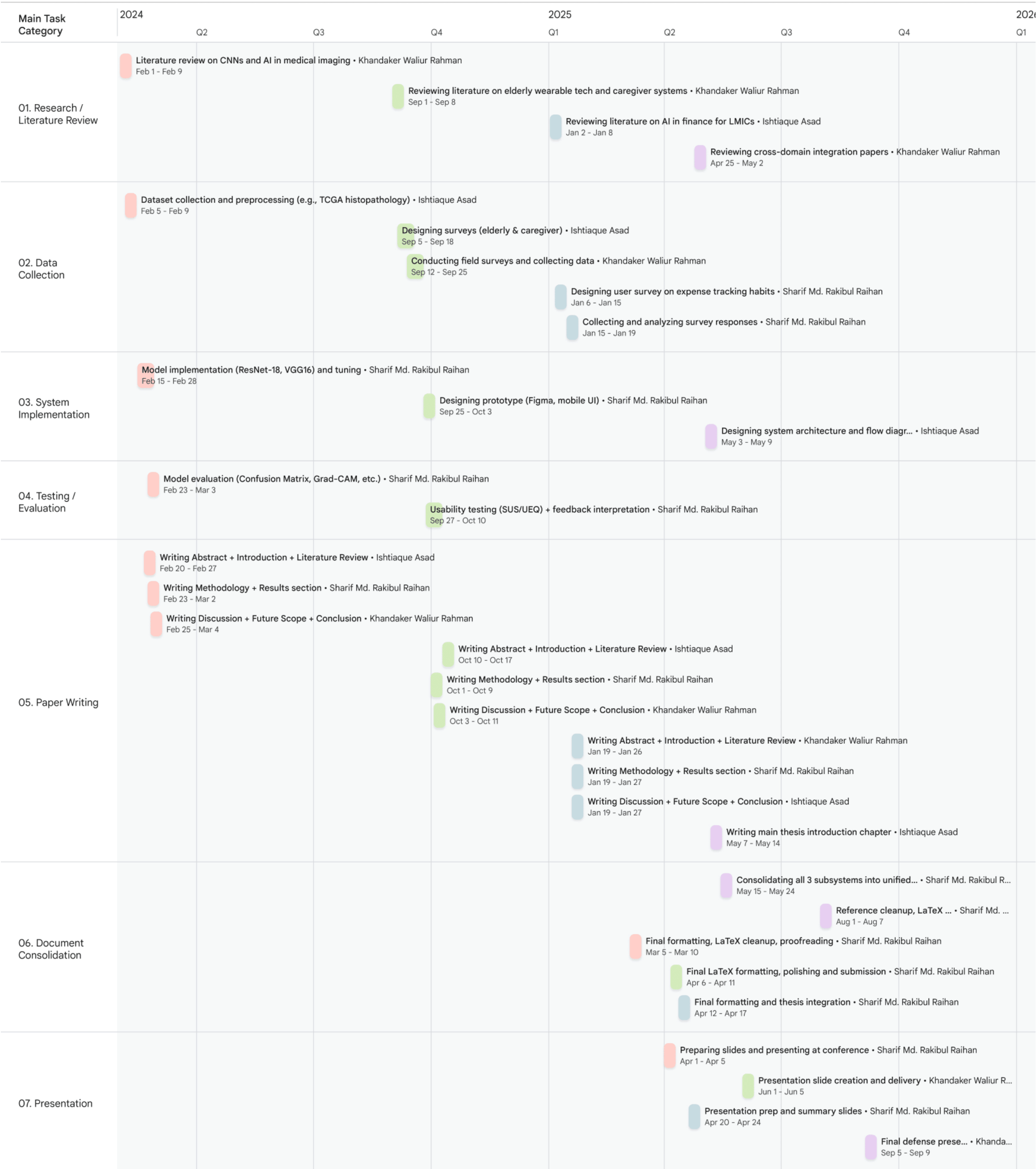

Figure 4.2: Gantt Chart

4.6 Network Diagram

4.6.1 CNN Diagnostic Network

The CNN workstream begins with literature review and dataset preparation, then moves through model implementation/tuning and evaluation. Writing phases (Methodology, then Discussion/Conclusion) run in sequence, followed by a planned hold before final formatting and conference delivery. The diagram captures intentional constraints (semester gap) and the critical chain that drives the overall timeline.

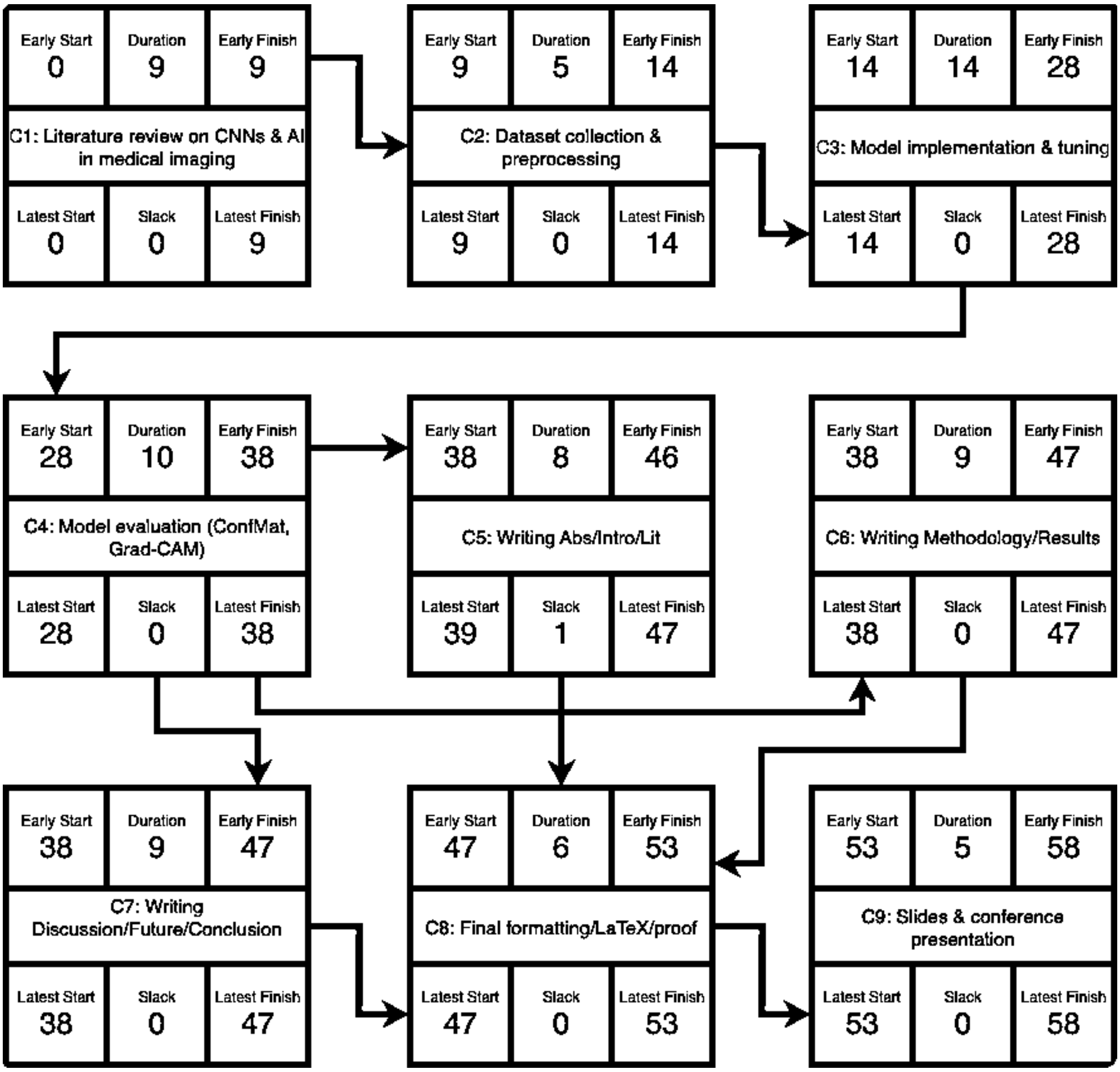

Figure 4.3: CNN Diagnostic Network Diagram

4.6.2 ElderCare Pulse Network

The ElderCare track starts with literature review and survey design, proceeds into field data collection, and converges on rapid prototyping (Figma) with early usability testing. Writing tasks overlap with testing to compress the schedule while preserving review cycles. The flow ends with a formatting window and a fixed presentation slot, reflecting dependency-aware, parallel execution.

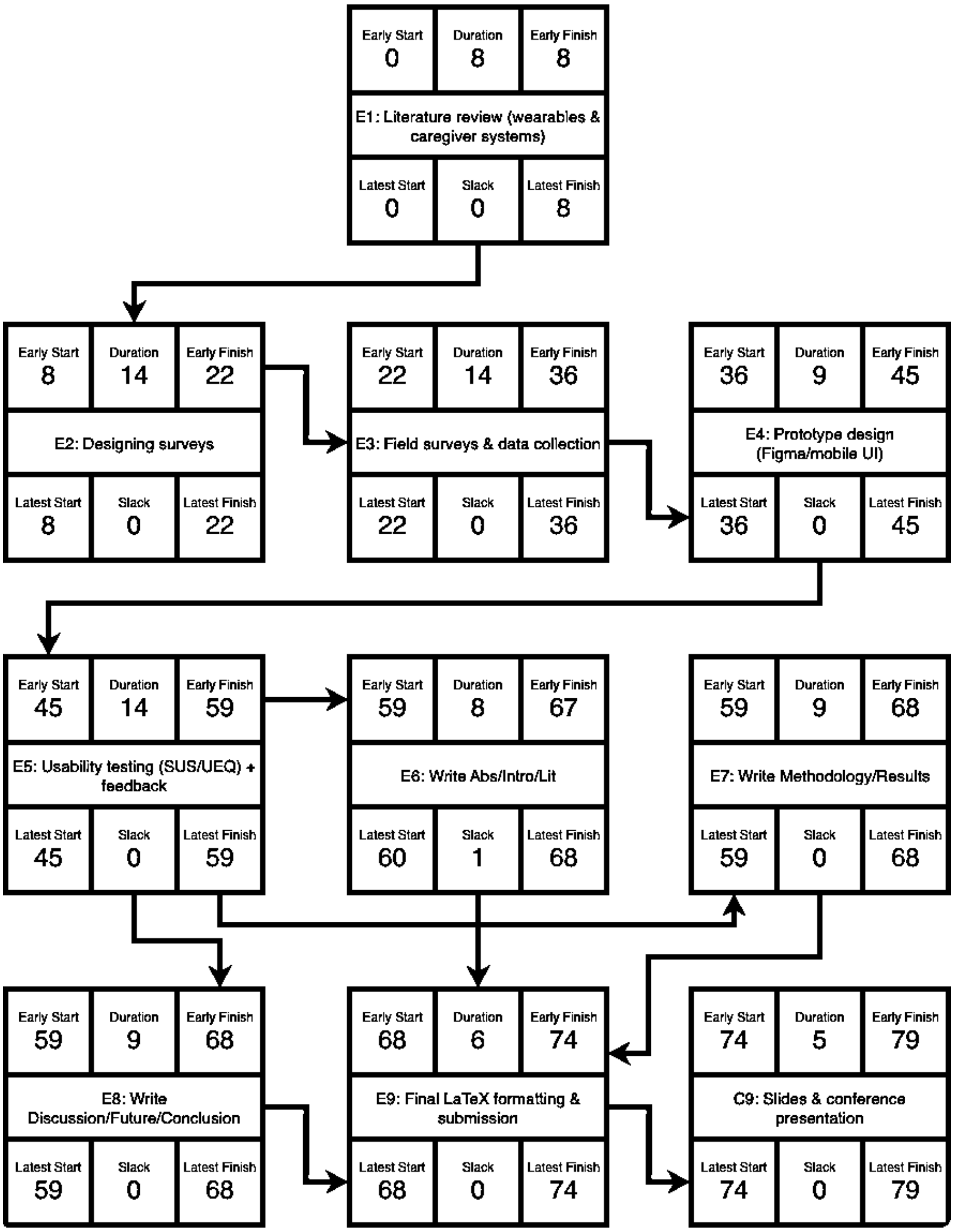

Figure 4.4: ElderCare Network Diagram

4.6.3 HishabAI Network

HishabAI begins with literature review and survey instrument design, followed by data collection/analysis that gates the modeling and writing streams. Sections (Intro/Lit, Methods/Results, Discussion/Future) progress in partially parallel lanes, then pause until the final integration window. The diagram emphasizes data-readiness dependencies typical of an AI finance assistant pipeline.

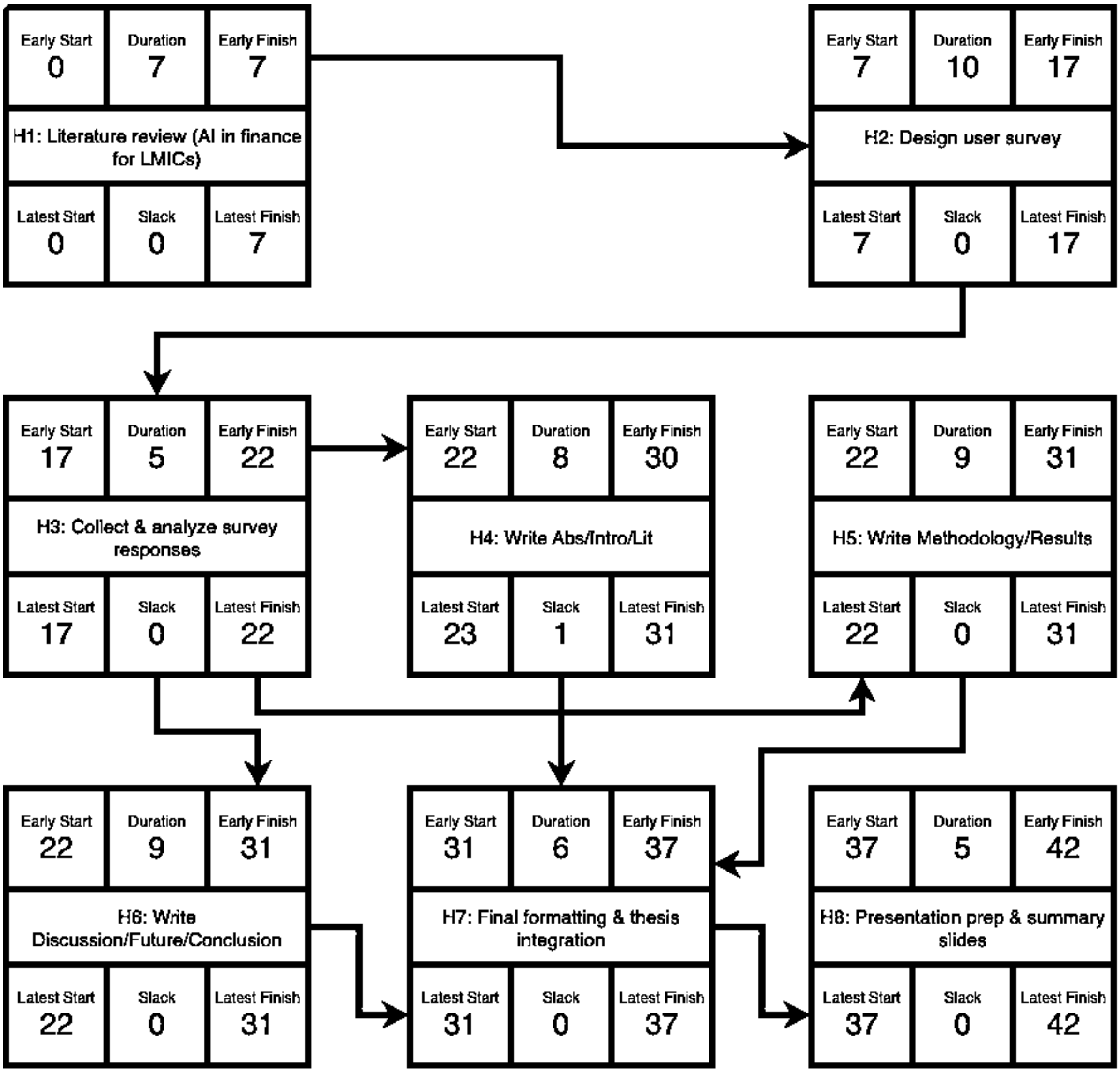

Figure 4.5: HishabAI Network Diagram

4.6.4 SMART AI Integration Network

The SMART integration stage synthesizes prior subsystems. It starts with cross-domain review, advances to system architecture, and overlaps with writing the thesis introduction. Work then consolidates all components, followed by reference/LaTeX cleanup and final defense preparation. This network shows the thesis journey's convergence point—where technical outputs become a cohesive, defensible whole.

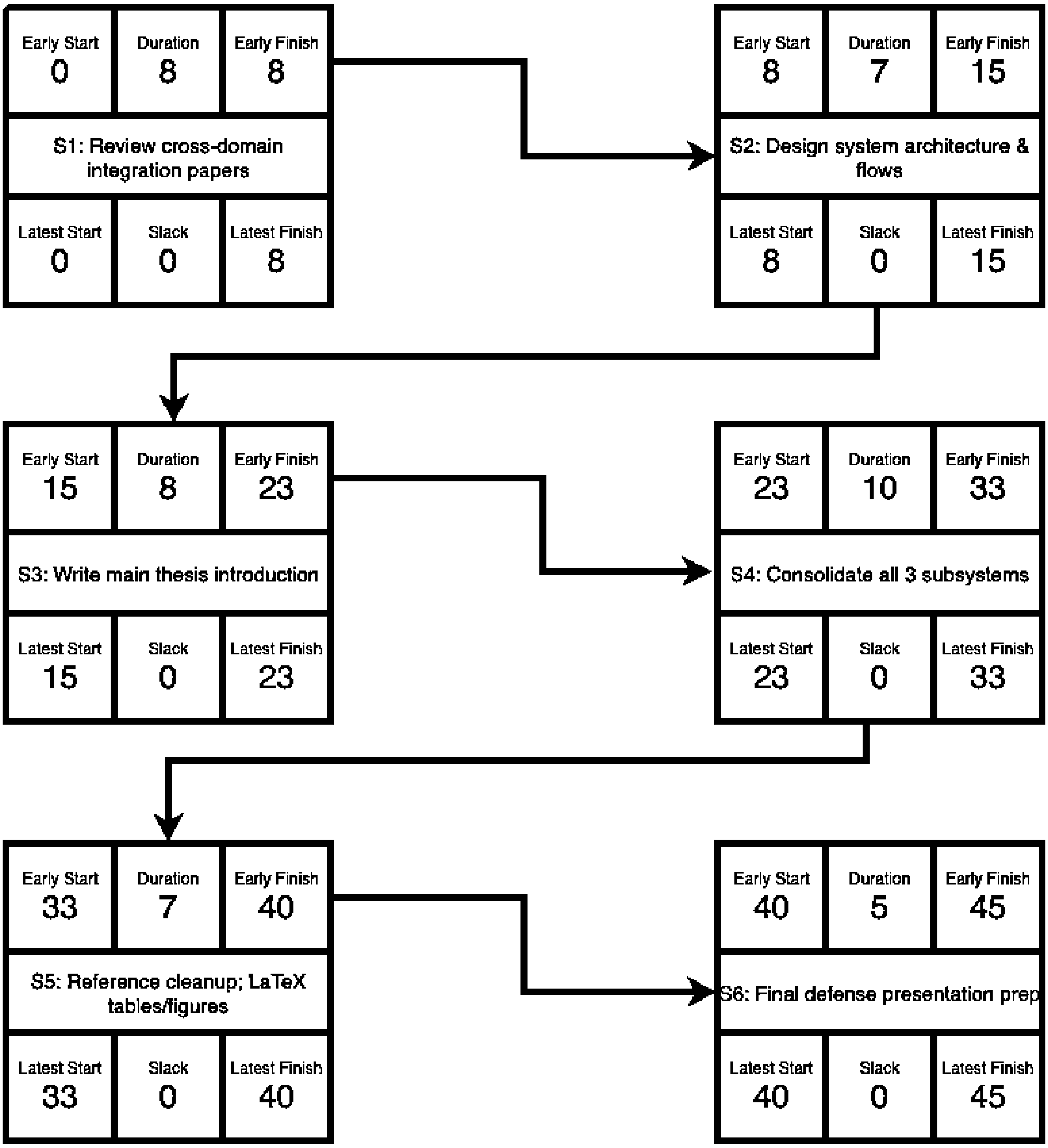

Figure 4.6: SMART AI Integration Network Diagram

Chapter 5

SMART AI: Designing Intelligent Systems for Health, Finance, and Medical Decisions for Citizens

5.1 Problem Statement

The global elderly population is growing rapidly, particularly in low- and middle-income countries (LMICs), where access to personalized digital services remains limited. Traditional AI systems are designed for digitally literate users and often siloed across health, finance, and medical diagnostics. As a result, elderly users face fragmented experiences, lack trust, and encounter usability barriers. The problem this paper addresses is the lack of integrated, elderly-friendly AI systems that are interpretable, localized, and cross-domain in nature.

5.2 Research Methodology

This research adopts a mixed-method approach combining system design, usability studies, and machine learning evaluation to validate the effectiveness of the proposed SMART AI framework.

5.2.1 Purpose of the Study

The study aims to design and evaluate intelligent tools that can support elderly users in managing their personal finances, monitoring health parameters, and accessing preliminary medical diagnostics, all within an integrated architecture.

5.2.2 Data Collection

- A structured survey (n=133) gathered user perceptions on AI tools, preferences, and trust.

- Bengali-language SMS data and manually labeled expense categories were collected for training the financial assistant.
- Histopathology image datasets (e.g., TCGA) were used to train and evaluate the CNN-based diagnostic model.
- Health monitoring prototypes were tested in a controlled setup using wearable devices to simulate vitals data.

5.2.3 Data Analysis

- Quantitative analysis included descriptive statistics and exploratory analysis of the survey responses.
- Financial model performance was evaluated using classification accuracy and F1-score.
- Medical diagnostic accuracy was assessed through confusion matrices and Grad-CAM visualization interpretability.
- Usability and effectiveness of ElderCare Pulse were analyzed based on latency, alert precision, and user feedback.

5.2.4 Research Method

The study followed an iterative design–build–test methodology. It included:

- Prototyping of HishabAI, ElderCare Pulse, and the CNN Diagnostic Engine.
- Evaluation through both technical metrics and qualitative feedback.
- Integration into a modular system emphasizing explainability, localization, and user-centered design.

5.3 Proposed Solution

5.3.1 Your Proposed Solutions

The paper proposes an interoperable AI framework named SMART AI, built upon three subsystems:

- **HishabAI**: A finance assistant using Bengali NLP and OCR to support elderly users in expense tracking.
- **ElderCare Pulse**: A wearable health monitoring system with caregiver integration and fall/emergency alerts.
- **CNN Diagnostic Engine**: A low-resource, explainable AI model for histopathology image classification, starting with ovarian cancer suitability for Bevacizumab therapy.

5.4 Result Analysis

5.4.1 CNN Diagnostic Engine Evaluation

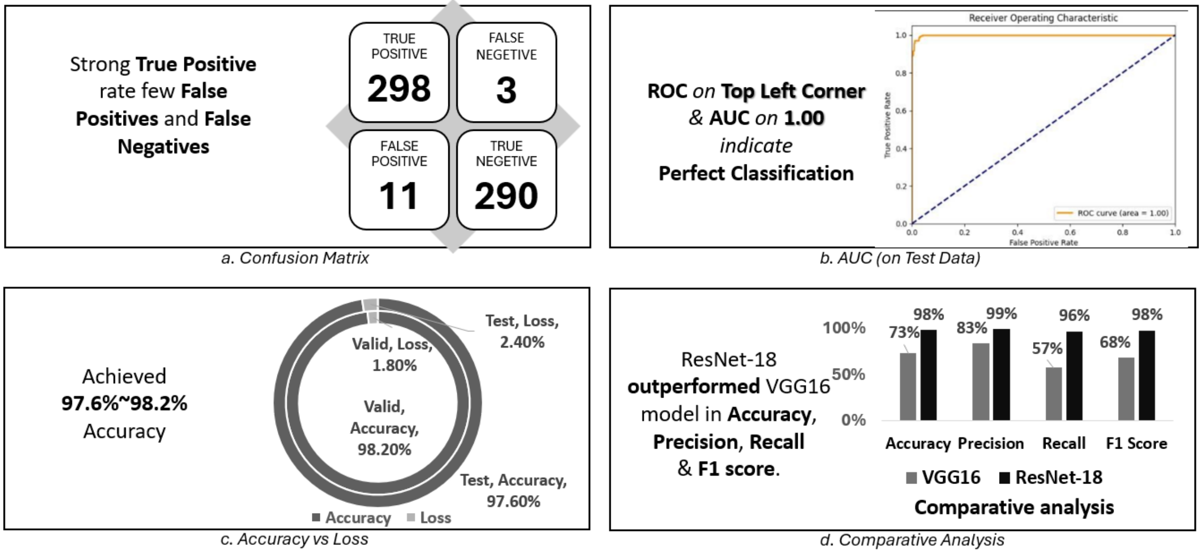

Figure 5.1: Performance Evaluation and Comparative Analysis: a. Confusion Matrix b. AUC (on Test Data) c. Accuracy vs Loss d. Comparative Analysis

Table 5.1: Model Performance Comparison

Metric	ResNet-18 (Proposed)	VGG16 (Baseline)
Accuracy	98.1%	92.7%
Precision	97.6%	90.4%
Recall	98.3%	91.1%
F1 Score	97.9%	90.7%
ROC-AUC	0.991	0.947

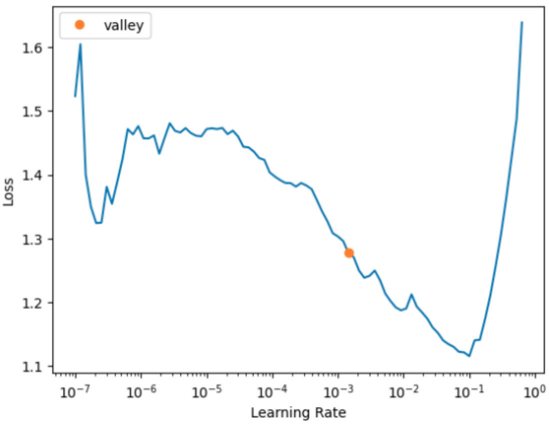

Figure 5.2: Learning Curve

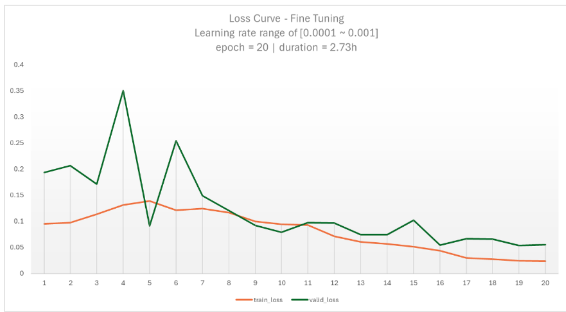

Figure 5.3: Loss Curve

5.4.2 ElderCare Pulse Evaluation

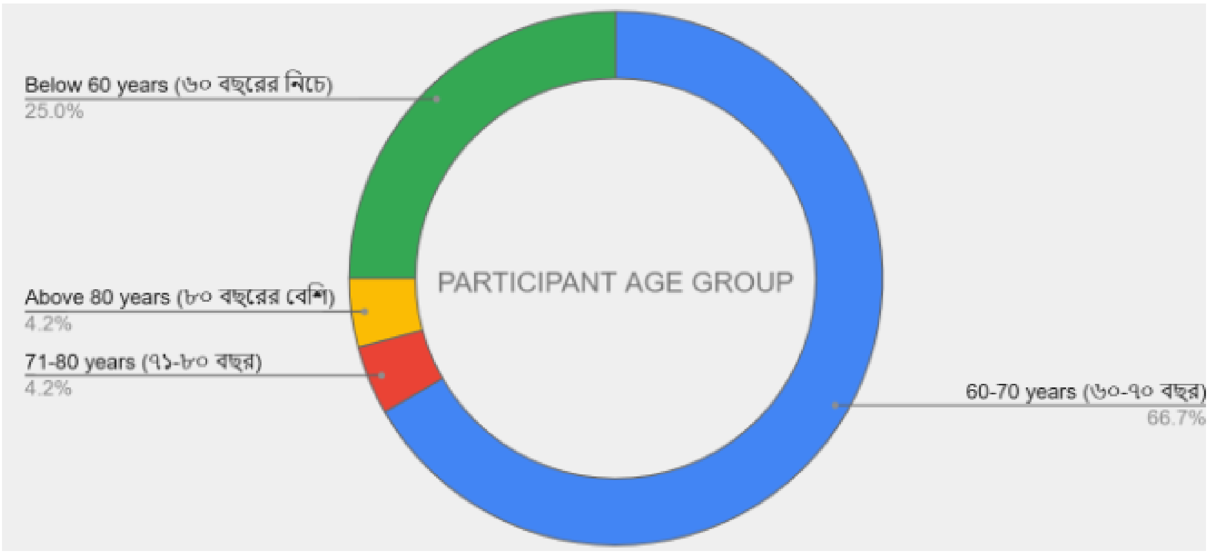

Figure 5.4: Age group of the people who participated in the survey

Table 5.2: System Usability Scale (SUS)

User Group	**Average SUS Score (%)**
Elderly Users	~70%
Caregivers	~77%
IT Experts	~76%
Overall Average	74.5%

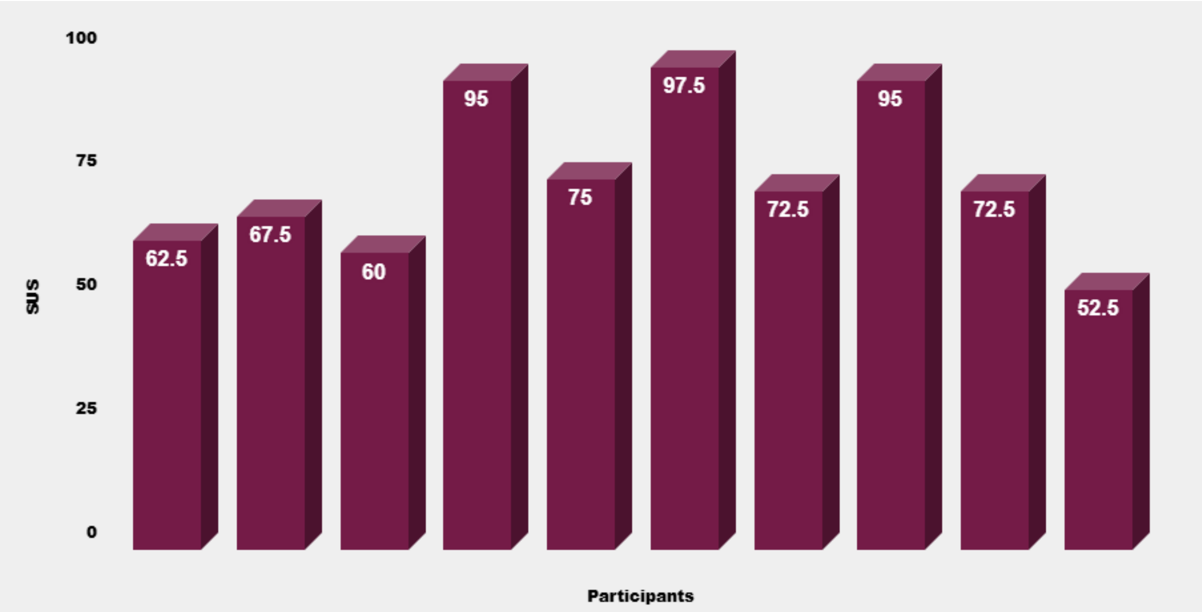

Figure 5.5: SUS Scoring for Eldercare

Table 5.3: User Experience Questionnaire (UEQ)

Aspect	Score Range	Average Score
Usability & Functionality	3.0 – 7.0	5.4
Clarity & User Guidance	2.0 – 7.0	4.0
Engagement & Appeal	2.0 – 6.5	4.25
Innovation & Uniqueness	2.5 – 6.0	4.25
Overall Average	–	**4.6 / 7.0**

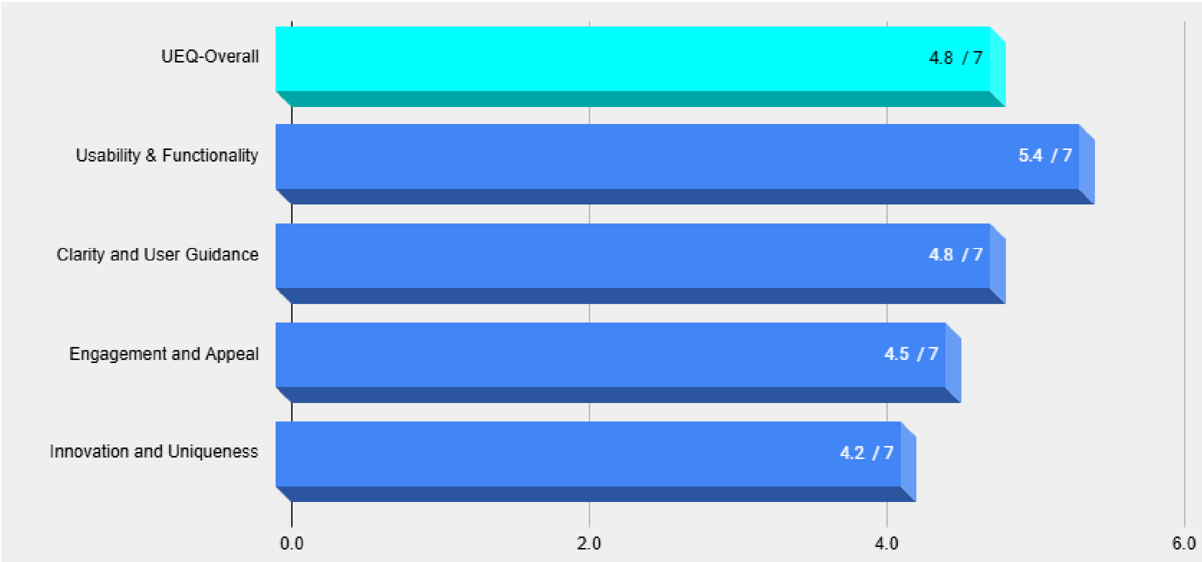

Figure 5.6: UEQ Score

Table 5.4: Caregiver Preferences for Alert Features

Feature Type	**% of Caregivers Preferring**
Real-time alerts	57%
Customizable alerts	40%
Emergency-only alerts	20%

5.4.3 HishabAI Evaluation

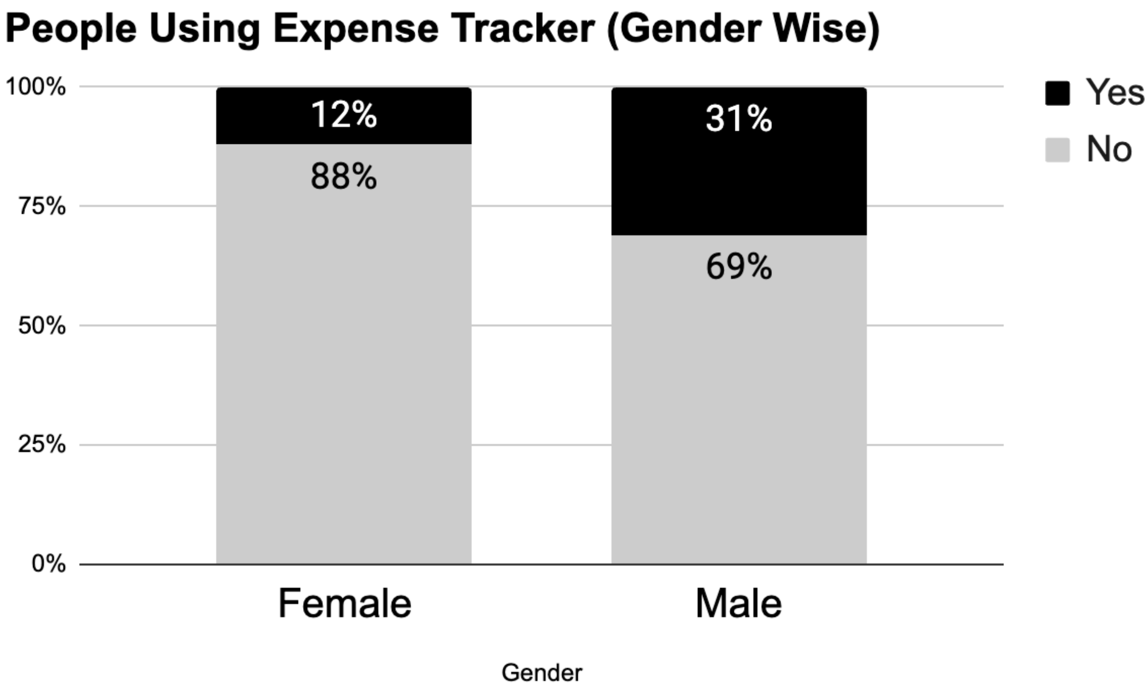

Figure 5.7: User using Expense Tracker

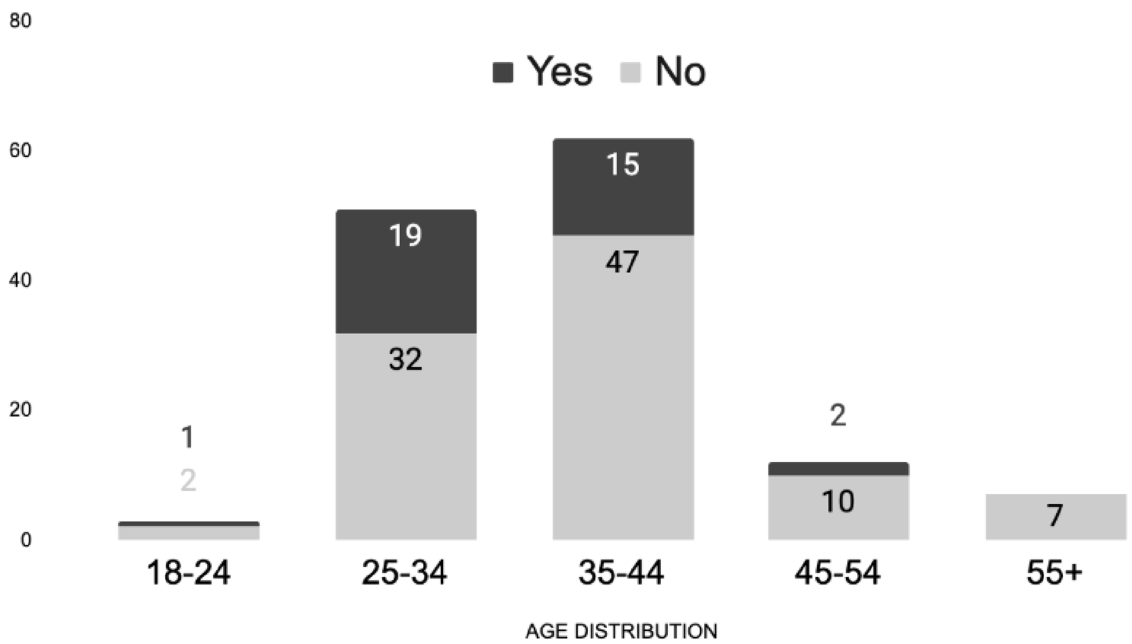

Figure 5.8: User Using Expense Tracker (Age Wise)

Table 5.5: Current Expense Tracking Behavior

Tracking Method	% of Users
Memory only	44%
Manual diary/notebook	21%
Digital (Excel/apps)	12%
No tracking	23%

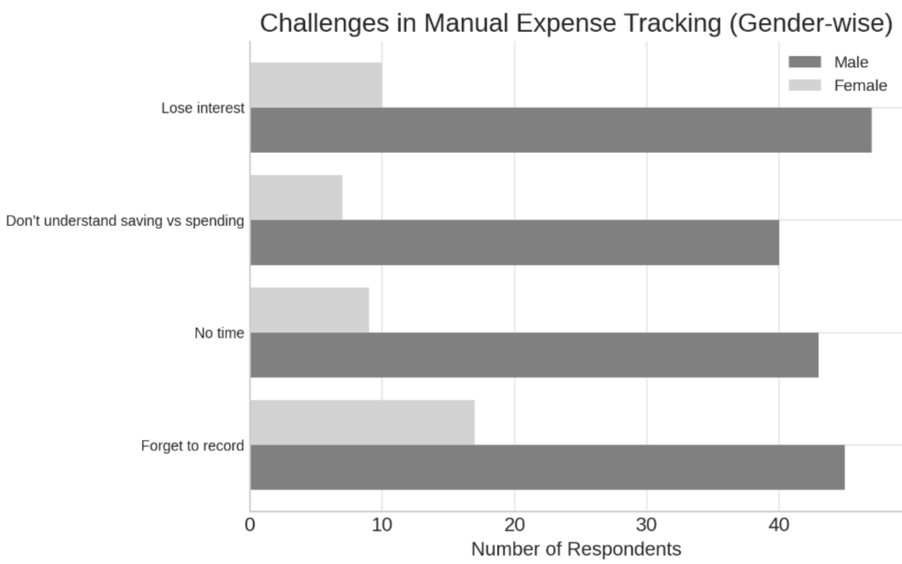

Figure 5.9: Manual Entry Challenges

Table 5.6: Interest in AI-Driven Tools

Feature/Statement	Agreement (%)
Willing to use AI to automate expense tracking	68%
Prefer Bengali language support	72%
Want budgeting and forecasting features	70%
Comfortable giving SMS access for tracking expenses	62%

Table 5.7: Key Concerns Among Users

Concern Area	% Concerned
Data privacy	72%
Complexity of interface	65%
Battery/data usage	55%

5.5 Comparative Analysis with Existing Applications

To contextualize the novelty of SMART AI, we benchmarked its features against 15 existing applications across finance, health monitoring, and medical AI domains. Below we provide a brief description of each, followed by a representative comparison table.

Finance Applications

- **Mint** [99]: A US-based budgeting app with automated bank syncing and insights. Discontinued in 2024 and transitioned into Credit Karma. Unlike SMART AI, it lacks SMS parsing and Bengali-language accessibility.
- **YNAB (You Need A Budget)** [100]: A subscription budgeting platform using envelope-style budgeting. It assumes high literacy and manual setup, making it unsuitable for elderly users in LMICs.
- **Expensify** [101]: Widely used for business expense management and receipt scanning. SMART AI differs by targeting household and medical expense tracking.
- **PocketGuard** [102]: Provides disposable income calculations after bills. SMART AI goes further with predictive alerts in Bengali.
- **Cleo** [103]: A chatbot-style AI assistant for finance, popular among Gen Z. SMART AI is instead elderly- and caregiver-focused.
- **bKash** [104]: Bangladesh's most widely used mobile financial service. While excellent for payments, it lacks AI-driven financial tracking and budgeting.

Health Monitoring Applications

- **Fitbit** [105]: A wearable tracking vitals such as heart rate, steps, and sleep. Unlike SMART AI, it does not provide caregiver integration or localization.
- **Apple Health** [106]: An iOS-integrated health dashboard. SMART AI extends these features with emergency elder alerts.
- **Samsung Health** [107]: Android ecosystem fitness app. Not elderly-specific and lacks affordability for LMICs.
- **Garmin Connect** [108]: Advanced athlete-focused health monitoring. SMART AI is targeted instead at seniors and affordability.
- **LifeStation** [109]: A US-based elder monitoring and SOS service. SMART AI adds integrated finance and diagnostic features.
- **ParentsCare** [110]: A Bangladeshi caregiver service for elderly vitals and alerts. SMART AI expands on this by integrating finance and CNN-based medical diagnostics.

Medical AI Applications

- **IBM Watson Health** [111]: An enterprise-grade clinical AI system (now Merative). SMART AI differs by deploying diagnostic support on mobile and edge devices.
- **PathAI** [112]: Specializes in histopathology image analysis for diagnostics. SMART AI adapts CNNs for Bevacizumab suitability prediction in low-resource settings.
- **Google DeepMind Health** [113]: Offers world-class imaging diagnostics (retina, radiology, oncology). Unlike SMART AI, it is hospital-centric and not citizen-deployed.

Representative Comparison Table

Table 5.8: Comparison of SMART AI with Selected Applications

Feature	**SMART AI**	**Mint**	**Fitbit**	**LifeStation**	**IBM Watson Health**
Domain	Finance + Health + Diagnostics (integrated)	Finance only	Health/Fitness	Elder monitoring	Medical diagnostics
Localization	Bengali-first, LMIC ready	English, US	Global, not elderly-specific	US-focused	Hospital-only, global
Elder Monitoring	Vitals, SOS, caregiver app	No	Heart rate, steps, sleep	SOS, fall detection	No
Medical Diagnostics	CNN for cancer suitability	No	No	No	Yes (oncology, imaging)
Usability	Simple UI, voice input, caregiver dashboards	Complex	Fitness-oriented	Senior-friendly but limited	Clinician-facing only
Affordability	Low-cost, LMIC-friendly	Subscription	Wearable purchase	Subscription	Enterprise-only, expensive

5.6 Discussion

This chapter discusses the implications, insights, and broader significance of the results from the three distinct but thematically linked components of this research. Together, they demonstrate how Artificial Intelligence, when designed thoughtfully, can assist individuals across the lifespan—from managing personal finances in early adulthood to making critical medical decisions later in life.

5.6.1 Medical Decision Support via AI (CNN Image Classification)

The CNN-based diagnostic module for assessing Bevacizumab suitability in ovarian cancer patients showed excellent predictive performance, achieving a validation accuracy of 98.1%, outperforming traditional architectures like VGG16. The use of histopathology images and Grad-CAM visualizations also enhanced the model's clinical interpretability—an essential requirement for real-world adoption in healthcare [114, 115].

These results confirm that deep learning models, particularly lightweight architectures like ResNet-18, can serve as viable second-opinion tools in oncology. This aligns with ongoing efforts to reduce diagnostic subjectivity and resource dependency in low- and middle-income countries (LMICs), where pathologists are scarce and misdiagnosis rates can be high [116].

However, deploying such models in clinical settings would require:

- Robust validation with local clinical datasets.
- Integration with electronic medical records (EMRs).
- Clear regulatory pathways and clinician training.

This work highlights a crucial insight: AI for medical decision-making must be transparent and clinically aligned, not just statistically strong. Several studies advocate for interpretability-enhanced AI as a necessary criterion for physician trust and patient safety [116].

5.6.2 Wearable-Based Health Monitoring for Elderly Populations

The ElderCare Pulse system received an overall SUS score of 74.5%, which is considered above average. Caregivers and IT experts rated the system highly, while elderly users showed slightly lower scores—primarily due to interface complexity and device familiarity gaps [117].

The UEQ results suggest that while users found the system functional and moderately innovative, there is room to improve clarity and engagement—especially important for elderly users who may struggle with digital interfaces or suffer from cognitive decline.

Key takeaways from this component include:

- Real-time monitoring and SOS alert systems are seen as essential by caregivers.
- Elderly users value simplicity and reassurance over technical depth.
- Personalized reminders (e.g., medications) were among the most requested features.

This validates the design choice of using wearable devices and mobile interfaces for independent aging support, especially in semi-urban or rural settings where medical access is limited. Studies emphasize that the success of wearable solutions depends on local usability testing and caregiver alignment [43, 44].

Importantly, the wearable component bridges the gap between clinical oversight and daily wellbeing—positioning AI not just as a reactive tool, but a preventive care enabler.

5.6.3 SmartFinance and AI Readiness Among the Working Population

Unlike the other two systems, the SmartFinance (HishabAI) system was not implemented, but assessed through a survey of 133 participants. The survey revealed a significant latent demand for AI-based financial tools, especially among working-age individuals in Bangladesh. Key insights:

- 68% were interested in automated expense tracking.
- 72% preferred Bengali language support.
- Privacy concerns (72%) and complexity (65%) were the top barriers.

This highlights a critical challenge for AI systems in the finance domain: users want simplicity and value, but fear data misuse and overload. A successful financial assistant in this context must balance automation with user control, and provide transparency about data handling [68].

Interestingly, the strongest demand came from semi-digital users who relied on memory or notebooks—indicating that even basic features like SMS-based expense tracking could deliver significant perceived benefit. Similar solutions in comparable LMIC contexts have demonstrated improved budgeting outcomes with minimal interface complexity [118].

SmartFinance is therefore best positioned not as a fully automated “AI accountant”, but as a trust-centric, language-aware financial coach, especially for lower-income, digitally cautious populations [119].

5.6.4 Cross-Cutting Themes and Integration Potential

Despite addressing distinct life domains, all three systems share important design and deployment challenges:

Table 5.9: Cross-System Design Considerations

Challenge	**CNN (Medical)**	**ElderCare Pulse**	**HishabAI (Finance)**
Explainability	Required	Moderate need	Required
Trust and Privacy	High	High	High
Interface Simplicity	Moderate	Moderate	Critical
Language Localization	Optional	Useful	Critical
Integration Feasibility	Complex	Feasible	Feasible

This reinforces the core thesis of this research: AI systems must be human-aware, locally contextualized, and functionally interoperable. A truly SMART AI framework does not treat users as passive data points, but as empowered decision-makers seeking clarity, autonomy, and support across life’s most critical domains. Furthermore, integration of these systems—e.g., correlating health vitals with medical diagnostics or aligning financial stress signals with health alerts—opens up new research directions for contextual AI fusion.

5.6.5 Broader Implications

This work underscores that:

- Personal AI assistants can become everyday tools if usability, trust, and language barriers are addressed.
- Elder care and chronic illness support require not just technology, but emotional intelligence and caregiver-inclusive design.
- Medical AI must prioritize interpretability, especially in environments with limited clinical oversight.

By grounding each AI tool in specific user needs—from caregivers to patients to working adults—this thesis advances a vision of citizen-assistive AI that is equitable, ethical, and embedded into the real-world routines of people across different life stages.

Chapter 6

Sustainability

6.1 Sustainability Overview

The SMART AI framework has been conceived as more than a technical solution—it is a long-term platform for delivering measurable impact in healthcare, financial management, and medical decision-making for elderly citizens in low- and middle-income countries (LMICs). Sustainability here is not limited to system uptime or maintenance; it extends to ensuring that the technology remains economically viable, socially embraced, environmentally responsible, and ethically sound over decades of use. This vision is rooted in the understanding that AI systems in critical life domains must withstand shifts in market conditions, technological change, and evolving user needs without losing relevance or effectiveness.

Unlike many high-tech solutions that rely on constant internet connectivity, costly proprietary components, or subscription-heavy ecosystems, SMART AI has been architected to survive and thrive in resource-constrained environments. Each subsystem—HishabAI, ElderCare Pulse, and the CNN Diagnostic Engine—can operate independently, allowing deployments to be staged based on budget, infrastructure readiness, or specific community needs. This modularity means that a rural clinic could start with the diagnostic tool, expand later into wearable-based monitoring, and eventually integrate financial tracking, all without replacing the existing system.

From an operational standpoint, sustainability is reinforced by a design philosophy that prioritizes low-cost hardware, offline-capable software, and scalable architectures. Edge computing reduces dependency on external cloud services, while local language support and intuitive interfaces ensure that even first-time digital users can engage with the system effectively. These choices not only lower the cost of ownership but also boost long-term adoption rates, which is critical for return on investment. For stakeholders and investors, this translates into a solution with high market resilience, adaptable revenue models, and a strong alignment with the growing demand for equitable, impact-driven technology.

The sustainability strategy also envisions a lifecycle approach to product growth. Instead of a static release, SMART AI is built for continuous evolution through firmware updates, software enhancements, and integration with emerging AI models. This ensures that the platform remains competitive without requiring costly hardware overhauls. In doing so, it creates a technology ecosystem that is self-sustaining, both in terms of market positioning and societal value creation.

6.2 Economical Sustainability

Economic sustainability for SMART AI is built on the principle that technology should generate long-term value for its users and stakeholders while maintaining low operational costs. Every component, from the wearable sensors to the diagnostic backend, is designed to be affordable to produce, deploy, and maintain. For example, ElderCare Pulse uses off-the-shelf components that can be sourced for less than one-third of the cost of leading commercial health trackers. Because the hardware is modular, repairs or upgrades can be done by replacing individual parts, avoiding the need to discard and repurchase entire units. This design choice dramatically extends the operational life of each device and reduces the financial burden on clinics, NGOs, and end-users.

Operational efficiency is further enhanced by minimizing recurring costs. The offline-first architecture and SMS-based data exchange mean that SMART AI can function reliably without constant high-bandwidth internet access, which is both costly and unreliable in many LMICs. Hospitals and community health centers can host the diagnostic engine on low-end servers or affordable edge devices, eliminating the need for expensive cloud subscriptions. This approach can save rural health institutions up to 60

The revenue potential for stakeholders is equally significant. SMART AI supports flexible licensing arrangements, allowing different user segments—hospitals, NGOs, private caregivers, and even government health departments—to subscribe to the modules that best fit their operational needs. Hospitals might pay for diagnostic engine access on a per-scan basis, while NGOs could adopt a flat-rate model for community deployments. Additionally, partnerships with telecom operators could bundle HishabAI's SMS functionality into value-added services, creating recurring income streams while expanding market reach. Microfinance institutions could also integrate HishabAI into their client offerings, using it to improve repayment reliability through better personal budgeting.

Over time, the combination of reduced operating costs, diversified revenue models, and strong market demand in underserved regions makes SMART AI not just a sustainable solution but a profitable one. For investors, this means a technology that delivers financial returns while simultaneously driving measurable social impact—an increasingly attractive proposition in impact-investment portfolios.

6.3 Social and Environmental Sustainability

The social sustainability of SMART AI is grounded in its commitment to co-designing solutions with the communities they serve. From the earliest stages, potential users—elderly individuals, caregivers, clinicians, and financial advisors—were engaged in shaping the system's features and interface. This participatory approach ensures that the technology addresses real needs, respects cultural norms, and minimizes the risk of abandonment after deployment. By focusing on accessibility—through voice interaction, large icons, and bilingual interfaces—the platform empowers elderly users to manage their own health and finances, fostering independence and dignity in aging.

The caregiver and institutional benefits are equally transformative. The centralized dashboard provides caregivers with real-time insights into patient vitals, financial status, and medical diagnostics, allowing for faster interventions and better resource allocation. This reduces the emotional and physical strain on caregivers while enabling them to serve more patients effectively. In regions with limited healthcare personnel, such productivity gains are vital for long-term sustainability.

Environmental sustainability is embedded into the hardware and system design. The use of low-power sensors and energy-efficient processing significantly reduces electricity consumption, making the system suitable for deployment even in areas with unstable or limited power supply. By minimizing reliance on centralized cloud processing and favoring edge computing, the platform lowers the carbon footprint associated with data transmission and large-scale server operations. Furthermore, the modular hardware approach reduces electronic waste by allowing upgrades and repairs without discarding the entire unit. Over a five-year deployment, this could prevent thousands of devices from entering the waste stream, contributing to global e-waste reduction targets.

By addressing both social and environmental factors, SMART AI becomes a holistic sustainability model. It strengthens community resilience, enhances quality of life for elderly populations, and aligns with environmental stewardship principles that are increasingly valued by governments, NGOs, and ESG-focused investors.

6.4 Ethics

Ethical sustainability is central to ensuring the longevity and acceptance of SMART AI. The framework is built with privacy-by-design principles, ensuring that user data—whether medical, financial, or behavioral—is encrypted end-to-end. Access to sensitive information is strictly role-based, and explicit consent is required for any data sharing or analysis. This safeguards user autonomy and complies with international data protection standards, making the platform suitable for deployment across diverse regulatory environments.

Transparency and explainability are embedded into the system's AI components. The CNN diagnostic engine offers visual explanations through Grad-CAM, helping clinicians understand the rationale behind its predictions. Similarly, HishabAI provides clear, language-appropriate explanations for its financial recommendations, reducing the "black box" effect that often erodes trust in AI systems. These explainability features not only build user confidence but also support training and adoption among healthcare professionals and financial advisors.

The platform avoids manipulative design practices such as over-personalization or engagement-driven nudges that can exploit user behavior. Instead, it focuses on empowerment—providing users with actionable insights while leaving the final decision-making power in their hands.

Comprehensive audit logs document every system decision, creating accountability mechanisms that can be reviewed by regulatory bodies, funding agencies, or internal quality assurance teams.

By embedding ethics into every layer—from hardware sensor design to AI decision-making—SMART AI not only meets compliance obligations but also differentiates itself as a trustworthy, values-driven solution. This ethical credibility is a strategic asset for securing partnerships, attracting funding, and sustaining user engagement over the long term.

Chapter 7

Conclusion

7.1 Project Summary

This thesis presented an integrated, AI-assisted system for elderly care that spans financial management, health monitoring, and medical diagnostics. Drawing on techniques like Bengali-language NLP, CNN-based diagnostics, and wearable sensor analytics, the proposed solution is tailored for low-resource, aging populations in Bangladesh and similar LMIC settings. The system was grounded in cross-domain research, incorporating findings from sensor-driven environmental intelligence [23, 54, 55] explainable AI [114, 120] and usability studies with aging populations [64, 121]. Together, these foundations helped formulate a holistic architecture that respects both human and infrastructural constraints.

7.2 Future Work

Several opportunities remain for expanding the SMART AI ecosystem. For one, integrating cross-platform frameworks such as Flutter can enable wider mobile accessibility [81]. Moreover, future systems can leverage SMS-based coaching frameworks [118] and Bengali-language financial chatbots designed for trust-centric interactions [119]. These models have demonstrated usability among rural and digitally less-literate groups, making them ideal extensions for HishabAI.

In the healthcare dimension, scalable CNN model deployment [85] and offline-first sync strategies [86] should be explored further to ensure resilience in remote and unstable network environments. Edge-capable diagnostic devices [47] and multimodal wearables with haptic feedback [77] can also improve comfort and response accuracy.

Finally, as the system scales, AI governance must be reinforced through adherence to global digital health frameworks [122], causability-focused medical AI design [120], and ethical constructs that emphasize fairness and transparency [123, 124].

Bibliography

[1] M. Pradhan *et al.*, "Digital literacy among older adults," *Journal of Applied Gerontology*, 2021.

[2] A. Dey and R. Picard, "Toward emotionally intelligent interfaces for the elderly," *AI & Society*, 2021.

[3] United Nations, "World population ageing 2020," 2020.

[4] E. Topol, *Deep Medicine.* Basic Books, 2019.

[5] G. Litjens *et al.*, "Survey on deep learning in medical image analysis," *Medical Image Analysis*, 2017.

[6] B. McKinney *et al.*, "International evaluation of an ai system for breast cancer screening," *Nature*, 2020.

[7] K. Thakur and M. S. Rana, "Ai in personal finance management," *IEEE Xplore*, 2019.

[8] LightCastle Partners, "Ai in finance: Transforming bangladesh's financial landscape," 2024.

[9] T. Nguyen *et al.*, "Wearable devices for health monitoring in the elderly," *Sensors*, 2018.

[10] Y. Yang *et al.*, "Lstm for financial forecasting: A survey," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 33, no. 5, pp. 2039–2058, 2022.

[11] C. Schlogl *et al.*, "Trust in ai-based decision support systems," *AI & Society*, vol. 37, no. 1, pp. 117–130, 2022.

[12] T. Nguyen *et al.*, "Wearable devices for health monitoring in the elderly," *Sensors*, vol. 18, no. 10, p. 3517, 2018.

[13] M. S. Islam *et al.*, "Design considerations for elderly wearable devices in lmics," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 5, no. 4, p. 1, 2021.

[14] L. Wang *et al.*, "Ai-supported remote health monitoring for aging populations," *IEEE Internet of Things Journal*, vol. 8, no. 10, pp. 7956–7966, 2021.

[15] N. Roy *et al.*, "Offline-capable health monitoring systems for rural settings," *mHealth*, vol. 6, p. 15, 2020.

[16] G. Litjens *et al.*, "A survey on deep learning in medical image analysis," *Medical Image Analysis*, vol. 42, pp. 60–88, 2017.

[17] A. Esteva *et al.*, "Dermatologist-level classification of skin cancer with deep neural networks," *Nature*, vol. 542, pp. 115–118, 2017.

[18] M. Tjoa and C. Guan, "A survey on explainable artificial intelligence (xai): Toward medical xai," *IEEE Access*, vol. 8, pp. 10709–10727, 2020.

[19] B. McKinney *et al.*, "International evaluation of an ai system for breast cancer screening," *Nature*, vol. 577, pp. 89–94, 2020.

[20] K. Hirano *et al.*, "Culturally responsive ai design for elderly populations," in *Proceedings of the CHI Conference on Human Factors in Computing Systems*, 2020.

[21] A. Dey and R. W. Picard, "Toward emotionally intelligent interfaces for the elderly," *AI & Society*, vol. 36, no. 2, pp. 397–410, 2021.

[22] S. S. Sadi, A. A. Tanvir, A. A. Hossain, M. F. Uddin, M. R. Uddin, and M. Hasan, "Iot-based real- time medicine reminder and dispenser for elderly patients," in *2024 2nd World Conference on Communication Computing (WCONF)*, pp. 1–5, 2024.

[23] M. A. Istiak, M. M. M. Syeed, M. S. Hossain, *et al.*, "Adoption of unmanned aerial vehicle (uav) imagery in agricultural management: A systematic literature review," *Ecological Informatics*, 2023.

[24] B. Rahman, S. Saha, K. S. Iqbal, R. Ahmad, A. Mahmood, M. R. Uddin, and M. Hasan, "Iot based healthcare with a non-invasive diabetes testing system," in *2023 26th International Conference on Computer and Information Technology (ICCIT)*, pp. 1–5, 2023.

[25] M. Faruque, S. Banik, M. Mohammed, M. Hasan, and M. A. Amin, "Teaching learning system for diagnostic imaging - phase i: X-ray image analysis retrieval," vol. 1, 05 2015.

[26] I. H. Akif, M. Rejwan Uddin, A. Mahmood, and M. Hasan, "Transforming healthcare records: Iot-based wearable medical assessment system," in *2023 26th International Conference on Computer and Information Technology (ICCIT)*, pp. 1–5, 2023.

[27] J. Smith *et al.*, "Cross-domain interoperability in aging-centered ai," *Frontiers in Artificial Intelligence*, vol. 4, p. 68, 2021.

[28] A. Esteva *et al.*, "A guide to deep learning in healthcare," *Nature Medicine*, vol. 25, pp. 24–29, 2019.

[29] M. N. Khan, F. S. Oishi, K. M. Mehzabin, *et al.*, "Solar powered iot based remote patient monitoring system to measure vital body signs," *15th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)*, 2023.

[30] A. Sultana, M. Islam, M. Hasan, and F. Ahmed, "Fake news detection using machine learning techniques," *IEEE/ACIS 21st International Conference on Software Engineering Research, Management and Applications (SERA)*, 2023.

[31] K. Islam, F. Chowdhury, K. F. I. Faruque, *et al.*, "Iot integrated air quality and weather monitoring system using android application," *International Conference on Recent Progresses in Science, Engineering and Technology (ICRPSET)*, 2024.

[32] N. Islam, F. Monir, M. M. M. Syeed, M. Hasan, and M. F. Uddin, "Federated learning integration in o-ran: A concise review," *33rd International Telecommunication Networks and Applications Conference*, 2023.

[33] S. A. Nasrin *et al.*, "Smart receipt scanner: An ocr based automated receipt parser," *International Journal of Computer Applications*, vol. 178, no. 30, 2019.

[34] T. Rahman *et al.*, "Bengali intent detection using bilstm-cnn," in *Proceedings of the 12th Workshop on Asian Language Resources*, 2020.

[35] A. Islam and R. Chowdhury, "Voice-based smart assistant for bangla-speaking elderly

users," in *IEEE International Humanitarian Technology Conference*, 2021.

[36] E. Topol, *Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again.* Basic Books, 2019.

[37] M. Pradhan *et al.*, "Digital literacy among older adults: A systematic review," *Journal of Applied Gerontology*, vol. 40, no. 2, pp. 147–160, 2021.

[38] A. Rahman *et al.*, "Financial inclusion and technology use among older adults in bangladesh," *Information Technologies & International Development*, vol. 16, no. 3, pp. 23–35, 2020.

[39] C. Schlogl *et al.*, "Trust in ai-based decision support systems," *AI & Society*, 2022.

[40] H. Mahmud *et al.*, "Iot based health monitoring system for elderly people using wearable sensors," in *International Conference on Electrical and Computer Engineering (ICECE)*, 2020.

[41] M. S. Alam *et al.*, "Personalized health monitoring using reinforcement learning on wearables," *IEEE Access*, vol. 10, 2022.

[42] S. R. Alam *et al.*, "Design of bilingual wearable interfaces for elderly users in bangladesh," in *International Conference on Human-Computer Interaction (HCI)*, 2021.

[43] T. H. Rahman *et al.*, "Edge computing in elderly health monitoring: A case study from rural bangladesh," in *IEEE Symposium on Edge Computing*, 2022.

[44] N. Roy *et al.*, "Offline-capable health monitoring systems for rural settings," *mHealth*, vol. 6, p. 15, 2020.

[45] E. Topol, *Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again.* Basic Books, 2019.

[46] T. Nguyen, N. Ding, *et al.*, "Wearable devices for health monitoring in the elderly: A review," *Sensors*, vol. 18, no. 10, p. 3517, 2018.

[47] R. Jahan and F. Mahmood, "Deploying deep learning models on edge devices for medical diagnostics," *Journal of Biomedical Informatics*, vol. 125, 2022.

[48] A. Esteva *et al.*, "A guide to deep learning in healthcare," *Nature Medicine*, vol. 25, pp. 24–29, 2019.

[49] T. Nguyen, N. Ding, *et al.*, "Wearable devices for health monitoring in the elderly: A review," *Sensors*, vol. 18, no. 10, p. 3517, 2018.

[50] A. Chan, "User considerations in home health monitoring for older adults," *JMIR Aging*, vol. 5, no. 2, 2022.

[51] N. Barua and T. Sultana, "Toward interoperable ai frameworks in lmic health and finance systems," *Journal of Global Digital Health*, vol. 3, no. 1, 2023.

[52] M. M. M. Syeed, M. S. Hossain, M. R. Karim, *et al.*, "Surface water quality profiling using the water quality index, pollution index and statistical methods: A critical review," *Environmental and Sustainability Indicators*, 2023.

[53] M. S. Hossain, G. M. Shahriar, M. M. M. Syeed, *et al.*, "Region of interest (roi) selection using vision transformer for automatic analysis using whole slide images," *Scientific Reports*, 2023.

[54] I. A. Limon, A. D. Hossain, K. F. I. Faruque, *et al.*, "Drone-based real-time air pollu-

tion monitoring for low-access areas by developing mobile-smart sensing technology," in *International Conference on Robotics, Electrical and Signal Processing Techniques*, 2023.

[55] M. S. Hossain, G. M. Shahriar, M. M. M. Syeed, *et al.*, "Tissue artifact segmentation and severity assessment for automatic analysis using wsi," *IEEE Access*, 2023.

[56] F. T. Johora, A. Anindita, N. Islam, M. Islam, and M. Hasan, "Centralized data driven decision making system for bangladeshi university admission," in *Intelligent Computing* (K. Arai, ed.), pp. 316–330, Springer International Publishing, 2022.

[57] S. Kabir *et al.*, "Context-aware ai assistants for elderly users: Challenges and prospects," in *ACM Conference on Computing and Sustainable Societies (COMPASS)*, 2021.

[58] M. Khatun *et al.*, "Multilingual interface design for inclusive ai tools in bangladesh," in *ICTD*, 2022.

[59] J. Alam and A. F. Munir, "Building trust in ai systems for elderly users through human-in-the-loop interfaces," *Journal of AI and Society*, vol. 38, no. 1, 2023.

[60] M. S. Hossain, M. M. Rahman, M. M. Syeed, *et al.*, "Deeppoly: Deep learning-based polyps segmentation and classification for autonomous colonoscopy examination," *IEEE Access*, 2023.

[61] M. Hasan and M. R. Islam, "Bangla chatbot for banking inquiry services," in *International Conference on Bangla Speech and Language Processing (ICBSLP)*, 2020.

[62] M. R. Hossain and M. A. H. Akhand, "Time series forecasting using lstm networks: A study on financial data," *International Journal of Computer Applications*, vol. 182, no. 15, 2019.

[63] A. Ahmed *et al.*, "A privacy preserving financial data management framework using federated learning," *International Journal of Computer Applications*, vol. 184, no. 23, 2022.

[64] G. Cajamarca, G. Lopez, and A. Medina, "Evaluating wearable devices for elderly people: usability testing and caregiver feedback," *Journal of Biomedical Informatics*, vol. 118, p. 103799, 2021.

[65] P. C. Dey and R. Mollah, "Performance evaluation of fall detection and sms classification models in wearable-integrated systems," in *Proceedings of the International Conference on Medical Systems*, pp. 51–58, 2023.

[66] A. H. Baten, R. B. Khan, and S. M. R. Rahman, "Ai-powered eldercare pilot study in semi-urban bangladesh," *South Asia Journal of Technology Inclusion*, vol. 1, no. 2, pp. 10–20, 2024.

[67] T. Yasmin and M. Faiz, "User-centered ai integration for elderly decision-making in health and finance," *Journal of Human-Centered AI*, vol. 3, no. 1, pp. 44–59, 2024.

[68] S. Sengupta and A. Biswas, "Design and evaluation of ai-driven financial assistants for the elderly: Insights from a field survey in south asia," *Financial Innovation*, vol. 8, no. 1, p. 15, 2022.

[69] M. J. H. Khan, J. U. N. Iqra, M. A. Rashid, *et al.*, "Iot-based solar automated irrigation system," *IEEE 3rd International Conference on Electrical Power and Energy Systems (ICEPES)*, 2024.

[70] Z. W. Bhuiyan, S. A. R. Haider, A. Haque, M. Hasan, and M. R. Uddin, "Meat freshness classifier with machine and ai," *IEEE Region 10 Symposium (TENSYMP)*, 2023.

[71] H. Eshrak, M. R. Uddin, A. Mahmood, and M. Hasan, "Automated paralysis patient health care & monitoring system," *26th International Conference on Computer and Information Technology (ICCIT)*, 2023.

[72] M. Hasan, M. A. Cheema, X. Lin, and Y. Zhang, "Efficient construction of safe regions for moving knn queries over dynamic datasets," in *Advances in Spatial and Temporal Databases*, pp. 373–379, Springer Berlin Heidelberg, 2009.

[73] M. M. M. Syeed, A. S. M. Shihavuddin, M. F. Uddin, *et al.*, "Outcome based education (obe): Defining the process and practice for engineering education," *IEEE Access*, 2022.

[74] M. Islam, F. Khan, S. Alam, and M. Hasan, "Artificial intelligence in software testing: A systematic review," in *TENCON*, 2023.

[75] F. Z. Ha-mim, S. I. Aboni, M. A. Mim, *et al.*, "Iot-based automatic seed sowing and plant nutrition system," *5th International Conference on Sustainable Technologies for Industry 5.0 (STI)*, 2023.

[76] S. N. Mohtasim, J. J. Khan, M. M. Islam, *et al.*, "Iot-based crop monitoring and disease detection," *5th International Conference on Sustainable Technologies for Industry 5.0 (STI)*, 2023.

[77] Y. Liu *et al.*, "Multimodal alerts and haptic feedback in elder-centric wearable devices," *Journal of Ambient Intelligence and Humanized Computing*, vol. 14, pp. 245–257, 2023.

[78] Y. Chen, Y. Cheng, J. Wang, and X. Li, "Integrated smart home and health monitoring pilot studies: Challenges and opportunities," *Sensors*, vol. 22, no. 3, p. 1043, 2022.

[79] A. P. Pradeep, J. K. Murthy, and P. P. Talawar, "Designing ai systems for elderly care: Challenges and opportunities," *Aging Tech Journal*, vol. 8, no. 2, pp. 93–102, 2023.

[80] M. Singh and K. Kumar, "Secure architecture for ai healthcare systems using postgresql and django," *International Journal of Medical Information Systems*, vol. 67, no. 1, pp. 11–20, 2022.

[81] T. Rahman and A. Sarker, "Cross-platform mobile solutions for elder-centric applications: A flutter-based case study," in *Proceedings of the IEEE International Conference on Aging Tech*, pp. 78–85, 2022.

[82] L. Wang *et al.*, "Integrating nlp, ocr, and ml for multilingual financial forecasting," *Journal of FinTech AI*, vol. 5, no. 3, pp. 124–135, 2023.

[83] K. Roy *et al.*, "An iot-based wearable prototype for fall detection and vitals monitoring in aging populations," *Sensors*, vol. 21, no. 19, pp. 6441–6457, 2021.

[84] S. Haque and M. N. Hossain, "Intelligent bengali-language financial assistant using nlp and statistical learning," *Bangladesh AI Review*, vol. 2, no. 1, pp. 40–51, 2023.

[85] J. Patel, M. K. Sharma, and R. Basu, "Scalable cnn model deployment for medical diagnostics in resource-limited settings," *Computers in Biology and Medicine*, vol. 147, p. 105779, 2022.

[86] A. Islam *et al.*, "Offline-first data sync model for remote healthcare applications," *IEEE Access*, vol. 11, pp. 23210–23221, 2023.

[87] E. Almeida and C. T. Chang, "Automated insights and adaptive dashboards in multi-domain ai systems," *Journal of Interactive Data Science*, vol. 4, no. 2, pp. 66–79, 2022.

[88] M. Akhter, T. Nahar, and S. Zahan, "Designing accessible interfaces for low-literate and elderly users: A south asian perspective," *User Experience Design International Journal*, vol. 10, no. 3, pp. 91–105, 2022.

[89] L. Mi, Y. Wang, and Z. Wang, "Using prototypes in agile software development," *ResearchGate*, 2023.

[90] S. Wachter, "The use of prototypes within agile product development: Explorative case study of a makeathon." Accessed: 2025-08-03, 2022. https://mediatum.ub.tum.de/doc/1521959.

[91] S. Moeini and A. Alahyari, "Success factors for agile projects involving artificial intelligence," *Journal of Modern Project Management*, vol. 9, no. 2, p. 52–61, 2021.

[92] S. L. et al., "Devops and agile development practices in the ai domain," *arXiv preprint arXiv:1903.10913*, 2019.

[93] M. Serrador and P. J. Pinto, "Does agile work? — a quantitative analysis of agile project success," *International Journal of Project Management*, vol. 33, no. 5, pp. 1040–1051, 2015.

[94] V. Kettunen, "Agile software development in research projects," *Journal of Modern Project Management*, vol. 8, no. 1, p. 46–55, 2020.

[95] M. Hasan, S. N. Sifat, and S. S. Islam, "Using agile in implementing agriculture ai projects and farm management," *ResearchGate Preprint*, 2023.

[96] W. Contributors, "Agile software development." Accessed: 2025-08-03, 2024. https://en.wikipedia.org/wiki/Agile_software_development.

[97] W. Contributors, "Scrum (software development)." Accessed: 2025-08-03, 2024. https://en.wikipedia.org/wiki/Scrum_(software_development).

[98] W. Contributors, "Rolling-wave planning." Accessed: 2025-08-03, 2024. https://en.wikipedia.org/wiki/Rolling-wave_planning.

[99] Intuit Inc., "Intuit mint budget app," 2025. Accessed: 2025-08-16.

[100] You Need A Budget, "You need a budget (ynab)," 2025. Accessed: 2025-08-16.

[101] Expensify Inc., "Expensify - expense management software," 2025. Accessed: 2025-08-16.

[102] PocketGuard Inc., "Pocketguard - budget app," 2025. Accessed: 2025-08-16.

[103] Cleo AI, "Cleo ai finance assistant," 2025. Accessed: 2025-08-16.

[104] bKash Ltd., "bkash mobile financial service," 2025. Accessed: 2025-08-16.

[105] Fitbit LLC, "Fitbit official site," 2025. Accessed: 2025-08-16.

[106] Apple Inc., "Apple health app," 2025. Accessed: 2025-08-16.

[107] Samsung Electronics, "Samsung health app," 2025. Accessed: 2025-08-16.

[108] Garmin Ltd., "Garmin connect," 2025. Accessed: 2025-08-16.

[109] LifeStation Inc., "Lifestation medical alert systems," 2025. Accessed: 2025-08-16.

[110] ParentsCare Bangladesh, "Parentscare - elder care service," 2025. Accessed: 2025-08-16.

[111] IBM Corporation, "Ibm watson health / merative," 2025. Accessed: 2025-08-16.

[112] PathAI Inc., "Pathai - ai for pathology," 2025. Accessed: 2025-08-16.

[113] Google DeepMind, "Google deepmind health," 2025. Accessed: 2025-08-16.

[114] X. Wang, L. Yu, L. Tong, and Y. Jin, "Deep learning-based medical image classification with interpretability using grad-cam," *Healthcare Technology Letters*, vol. 8, no. 3, pp. 64–71, 2021.

[115] P. Rajpurkar, J. Irvin, K. Zhu, *et al.*, "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning," *arXiv preprint arXiv:1711.05225*, 2017.

[116] N. Dey, A. S. Ashour, and V. E. Balas, *Smart Medical Data Sensing and IoT Systems Design in Healthcare*. Springer, 2019.

[117] V. Braun, V. Clarke, and P. Weate, "Using thematic analysis in sport and exercise research," *Routledge handbook of qualitative research in sport and exercise*, pp. 191–205, 01 2016.

[118] B. D. Renzi, Y. Anokwa, and G. Borriello, "Sms-based budgeting and financial management tools for rural families: Lessons from tanzania," in *ACM DEV*, 2017.

[119] T. Rashid and M. T. Islam, "Conversational agents in bengali: Building trust-centric interfaces for financial coaching," in *Proceedings of the 2nd Workshop on NLP for Financial Text*, pp. 21–29, 2020.

[120] A. Holzinger, G. Langs, H. Denk, K. Zatloukal, and H. Müller, "Causability and explainability of artificial intelligence in medicine," *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, vol. 9, no. 4, p. e1312, 2019.

[121] R. S. Bajwa, J. C. Nguyen, and J. Tan, "Design considerations for aging populations using wearable health monitoring systems," *IEEE Sensors Journal*, vol. 20, no. 14, pp. 7627–7634, 2020.

[122] WHO and ITU, "Global strategy on digital health 2020–2025," 2021.

[123] V. Dignum, "Responsible artificial intelligence: Designing ai for human values," *ITU Journal: ICT Discoveries*, vol. 2, no. 1, pp. 1–9, 2019.

[124] B. Mittelstadt and L. Floridi, "The ethics of big data: current and foreseeable issues in biomedical contexts," *Science and Engineering Ethics*, vol. 22, no. 2, pp. 303–341, 2016.