Athletix - A Fitness Intelligence Technology

Project Team

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Acknowledgements

We would like to express our sincere gratitude to our supervisor, **Dr. Muhammad Amin**, for his invaluable guidance and continuous support throughout this project. We also extend special thanks to **Dr. Znair Azam**, a fitness trainer and nutritionist, for serving as our domain expert and helping us bridge the gap between fitness science and technology. Lastly, we thank our families and peers for their constant encouragement and motivation during this journey.

Khawaja Mohammad Abdullah Ishaq

Azhan Shoaib

Subhan Tariq

Abstract

Athletix – Fitness Intelligence Technology is an AI-powered mobile fitness application that provides *personalized workouts, culturally aware diet plans, and real-time form analysis*. The app bridges the gap between traditional fitness coaching and digital health intelligence through Machine Learning (ML), Computer Vision (CV), Reinforcement Learning (RL), and Natural Language Processing (NLP).

The system uses an **HRNet-based pose estimation model** for real-time form feedback and a **Retrieval-Augmented Generation (RAG)** based Virtual AI Trainer to handle user queries related to workouts, equipment, and nutrition. Diet plans are generated using **constraint-based optimization** and adapted through **contextual bandits (RL)** based on user progress, goals, and constraints (e.g., medical, cultural, dietary).

This project contributes a scalable, adaptive, and inclusive AI solution that delivers safe, intelligent, and data-driven fitness guidance, addressing the lack of personalization, real-time feedback, and accessibility in existing fitness platforms.

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Chapter 1

Introduction

1.1 Purpose of the Investigation

The purpose of this study is to develop **Athletix – Fitness Intelligence Technology**, an AI-powered mobile application that bridges the gap between human coaching and digital fitness solutions. The system aims to deliver a personalized, adaptive, and inclusive fitness experience by leveraging the latest advancements in Machine Learning (ML), Computer Vision (CV), Reinforcement Learning (RL), and Natural Language Processing (NLP). The goal is to make professional-grade fitness guidance accessible, culturally adaptable, and data-driven for users of all fitness levels.

1.2 Problem Being Investigated

Current fitness applications and human trainers suffer from several limitations. Fitness apps often rely on generic workout and diet templates that fail to consider individual body composition, biomechanics, or medical and cultural constraints. Conversely, personal trainers, while more tailored, are costly and not scalable for everyone. Furthermore, existing digital solutions lack real-time form feedback, which increases injury risk and reduces exercise effectiveness. There is a critical need for a unified platform that offers intelligent, evidence-based, and personalized guidance to improve safety, efficiency, and user engagement in fitness.

1.3 Background and Importance of the Problem

Over the past decade, digital health and fitness applications have become mainstream. According to studies such as *"Mobile Apps for Human Nutrition: A Review"* by Ahmad et al. (2022) and *"Real-Time Fitness Exercise Classification and Counting"* by Riccio (2021), most apps fail to integrate validated physiological models or biomechanics-aware feedback. These shortcomings reduce the accuracy of training outcomes. At the same time, advances in pose estimation models like HRNet have demonstrated state-of-the-art results in human body tracking, opening opportunities for automated form correction. Similarly, Retrieval-Augmented Generation (RAG) and domain-specific Large Language Models (LLMs) enable intelligent conversational trainers that can answer user queries contextually and safely. Combining these emerging technologies can revolutionize personal fitness by providing adaptive, real-time, and expert-backed guidance at scale.

1.4 Thesis and General Approach

This project proposes a hybrid AI system that combines computer vision, machine learning, and reinforcement learning to create an intelligent, adaptive fitness assistant. The **Virtual AI Trainer** employs a fine-tuned **RAG-based LLM** to answer user queries about exercises, equipment, diet, and recovery. The **Form Analysis Module** uses **HRNet-based pose estimation** to provide biomechanics-aware real-time feedback during workouts. Personalized workout and diet plans are generated through **contextual bandits** and **constraint-based optimization**, ensuring cultural, medical, and physical adaptability. Continuous learning via reinforcement learning allows the system to evolve with each user's progress and feedback.

1.5 Criteria for Study Success

The success of the project will be determined through:

- Achieving at least 90% accuracy in HRNet-based form detection and classification of correct vs. incorrect posture.
- Generating diet plans with over 85% macro and calorie compliance based on user goals.
- Providing contextually accurate answers in at least 88% of AI trainer interactions using RAG + LLM.
- Maintaining sub-second (less than 0.5s) latency for on-device inference to ensure real-time feedback.
- Positive feedback from domain experts and test users in terms of usability, personalization, and engagement.

1.6 Summary

In summary, Athletix represents a next-generation digital fitness solution that integrates real-time computer vision, adaptive intelligence, and domain expertise to deliver an evidence-first, user-centric training experience. By merging fitness science with AI, the system aims to democratize access to personalized, safe, and effective fitness guidance globally.

Chapter 2

Review of Literature

2.1 Introduction

The growing integration of artificial intelligence in the fitness and health sector has transformed how users engage with physical training and nutrition management. However, despite the surge in mobile health applications, many existing solutions lack adaptive personalization, real-time feedback, and contextual understanding. This literature review focuses on identifying the gaps in current fitness and nutrition technologies and evaluating modern approaches in computer vision, reinforcement learning, and large language models that can be leveraged to develop **Athletix – Fitness Intelligence Technology**.

The review examines research in five key domains: (1) fitness app usability and adoption, (2) exercise classification and posture detection, (3) diet and nutrition recommendation systems, (4) retrieval-augmented and conversational AI systems, and (5) adaptive learning through reinforcement models.

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2.2 Body

2.2.1 Fitness Applications and Adoption

Vishwanath Swaminathan and Dr. Santosh Kumar Pattanayak (2021) analyzed the factors influencing consumer adoption of smartphone-based fitness applications. Their study highlighted that while accessibility and motivation are strong adoption drivers, retention drops significantly due to the lack of personalization and validated feedback mechanisms. This underscores the need for applications that dynamically adapt to user performance and goals.

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2.2.2 Exercise Classification and Real-Time Form Analysis

Riccio (2021) proposed a computer vision-based approach for real-time exercise classification and repetition counting from video frames. Using convolutional neural networks (CNNs) and pose estimation, the study achieved efficient classification of body movements but lacked biomechanics-aware error detection, which is essential for injury prevention. **Guo et al. (2020)** extended this concept with hybrid deep-learning models combining CNNs and LSTMs to analyze sequential movement data, improving temporal accuracy. However, neither model adjusted for individual body proportions—a gap Athletix addresses through HRNet-based pose estimation personalized by user body attributes.

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2.2.3 Nutrition and Dietary Recommendation Systems

Ahmad et al. (2022) conducted a comprehensive review on mobile apps for human nutrition, noting that most existing systems depend on manual data entry and lack localized dietary adaptation. Their findings emphasize the importance of culturally aware and automatically generated meal recommendations. **Müller et al. (2020)** introduced a constraint-based optimization model for personalized diet planning. This mathematical approach ensures balanced macro- and micronutrient intake under cultural and medical constraints, which Athletix adopts for safe and adaptive meal generation.

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2.2.4 Retrieval-Augmented and Conversational AI

Lewis et al. (2020) introduced **Retrieval-Augmented Generation (RAG)** to enhance LLM responses using external verified data sources. The model combines dense passage retrieval with generative capabilities, allowing accurate and contextually relevant responses. In fitness contexts, this architecture ensures that user queries—such as exercise substitution or recovery advice—are answered based on authenticated data rather than generic internet text, improving safety and trustworthiness.

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2.2.5 Adaptive Learning via Reinforcement Models

Zhao et al. (2021) and **Tong et al. (2021)** applied reinforcement learning to optimize user engagement in personalized recommendation systems. Their findings show that contextual bandits—an RL variant—can effectively balance exploration (trying new recommendations) and exploitation (reinforcing effective plans). Athletix utilizes contextual bandits to continuously refine workout and diet recommendations based on user adherence, fatigue, and satisfaction, thus ensuring adaptive intelligence and user retention.

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2.2.6 Pose Estimation and HRNet Advancements

Sun et al. (2019) presented HRNet (High-Resolution Network), which maintains high-resolution representations through the network pipeline, outperforming predecessors like

OpenPose and MoveNet in precision. HRNet's ability to preserve spatial detail makes it ideal for detecting subtle posture deviations—key to Athletix's real-time biomechanics-aware form analysis.

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2.2.7 Integration of Expert Feedback and Validation

Few systems integrate human expertise into model validation. Athletix incorporates insights from **Dr. Znair Azam**, a trainer and nutritionist, ensuring that exercise form validation, diet recommendations, and adaptive logic align with real-world fitness science.

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2.3 Comparative Analysis of Reviewed Literature

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2.4 Conclusion

The reviewed literature indicates a significant opportunity for integrating multiple AI domains—Computer Vision, NLP, and Reinforcement Learning—into a cohesive and adaptive fitness platform. Current systems either excel in one domain or lack contextual personalization. By combining HRNet for real-time pose estimation, constraint-based optimization for dietary planning, and RAG-driven conversational intelligence, Athletix addresses these limitations holistically. Furthermore, integrating domain expert feedback ensures practical validation, making Athletix a comprehensive, safe, and intelligent fitness companion.

Table 2.1: Comparative Analysis of Reviewed Literature

Study	**Focus Area**	**Methodology / Limitation**	**Relevance to Athletix**
Swaminathan et al. (2021)	Fitness app adoption	Survey-based; lacked adaptive feedback	Informed personalization and motivation strategies
Riccio (2021)	Exercise classification	CNN for pose analysis; no biomechanics integration	Basis for HRNet-based form correction
Guo et al. (2020)	Sequential motion detection	CNN-LSTM hybrid for temporal accuracy	Extended to adaptive pose feedback
Ahmad et al. (2022)	Nutrition app review	Manual diet entry, no cultural adaptation	Motivated automated diet input using constraint models
Müller et al. (2020)	Diet optimization	Constraint-based optimization model	Adopted for Athletix adaptive diet generation
Lewis et al. (2020)	Retrieval-Augmented Generation (RAG)	Enhanced LLM factual grounding	Used for AI Trainer knowledge retrieval
Zhao et al. (2021)	RL in personalization	Contextual bandit optimization	Applied to adaptive workout/diet progression
Sun et al. (2019)	Pose estimation (HRNet)	Maintained high-resolution feature maps	Core model for Athletix form analysis module
Tong et al. (2021)	User adherence modeling	Reinforcement learning for motivation	Used for progress tracking and behavioral retention

Chapter 3

Project Vision

3.1 Problem Statement

The fitness industry has seen tremendous digital growth, yet most existing solutions fail to deliver personalized, adaptive, and contextually relevant guidance. Current fitness applications rely on static templates for workouts and diets, overlooking individual differences in body mechanics, health conditions, and cultural preferences. Human trainers, while effective, are costly and geographically limited, creating accessibility barriers. Moreover, the absence of real-time form correction in most digital solutions leads to improper exercise execution, resulting in injuries or reduced efficiency. There is a clear need for an intelligent fitness companion that integrates real-time form analysis, adaptive learning, and personalized nutrition into a unified platform accessible to everyone.

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3.2 Business Opportunity

The global fitness technology market is expanding rapidly, driven by increased health awareness and smartphone penetration. However, most available apps—such as MyFitnessPal, Fitbod, or Nike Training Club—offer generic programs or rely on manual data entry. **Athletix** addresses this gap by providing an AI-driven, all-in-one fitness companion that offers:

- Real-time biomechanics-aware form analysis using HRNet.
- Personalized workout and diet recommendations using Machine Learning and Reinforcement Learning.
- A domain-verified Virtual AI Trainer (RAG + LLM) for interactive guidance and feedback.
- Cultural and medical adaptability (e.g., halal, vegan, diabetic-friendly diets).

This positions Athletix as a scalable and competitive product that bridges the gap between human expertise and accessible AI-driven health coaching. It has potential commercial viability through subscription-based services, expert integrations, and partnerships with fitness and healthcare organizations.

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3.3 Objectives

The primary objectives of this project are as follows:

1. To develop a Virtual AI Trainer capable of answering user queries regarding fitness, exercises, equipment, and nutrition using a RAG-based fine-tuned LLM.
2. To design a real-time form analysis module using HRNet-based pose estimation and biomechanics-aware rules for posture correction.
3. To implement an adaptive workout and diet planning system using contextual bandits and constraint-based optimization for progressive improvement.
4. To track user progress and provide visual analytics through an intuitive dashboard.
5. To ensure inclusivity and accessibility by providing culturally and medically adaptable fitness plans.

6. To validate the system's accuracy and usability through testing with real users and expert supervision.

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3.4 Project Scope

Athletix will be developed as a cross-platform mobile application that integrates multiple AI technologies to deliver a holistic fitness solution. The project scope includes:

- **Core Features:** Virtual AI Trainer, real-time form analysis, adaptive workout and diet generation, progress tracking, and AI-driven feedback.
- **Technologies Used:** React Native (frontend), FastAPI (backend), TensorFlow Lite (on-device inference), PyTorch (model training), PostgreSQL (data storage), and FAISS (vector retrieval for AI Trainer).
- **Data Sources:** Custom form datasets (recorded locally), COCO/MPII for pose keypoints, USDA FoodData Central for nutrition, and verified fitness QnA corpora for RAG.
- **Expected Deliverables:** A fully functional prototype mobile app with trained AI modules, evaluated on accuracy, efficiency, and user satisfaction.

The project will not initially include wearable sensor integration, multi-language support, or cloud-based federated learning, which are reserved for future work.

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3.5 Constraints

- **Hardware Constraints:** Mobile devices have limited computational power, requiring model optimization (quantization and pruning) for real-time inference.

- **Data Constraints:** Limited availability of diverse local datasets for fitness poses and culturally specific diets.
- **Connectivity Constraints:** RAG-based model queries may require online access for full functionality.
- **Ethical and Privacy Constraints:** User body data and video streams must be handled securely, ensuring privacy and data protection.
- **Time Constraints:** Development and testing must be completed within the academic year (10 months), limiting large-scale user trials.

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3.6 Stakeholders Description

The project involves several stakeholders directly or indirectly contributing to its success.

3.6.1 Stakeholders Summary

Table 3.1: Stakeholders Summary

Stakeholder	**Role**	**Interest / Contribution**
Project Team (Abdullah Ishaq, Azhan Shoaib, Subhan Tariq)	Developers and Researchers	Responsible for design, development, testing, and documentation of Athletix.
Supervisor	Academic Guide	Provides technical supervision and evaluates project progress.
Domain Expert (Dr. Znair Azam)	Fitness and Nutrition Consultant	Validates exercise biomechanics and diet planning modules.
End Users	Application Users (Beginners to Intermediate)	Benefit from adaptive workout, diet planning, and real-time feedback.
University	Academic Institution	Evaluates project quality and contribution to applied AI learning.

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3.6.2 Key High-Level Goals and Problems of Stakeholders

- **Project Team:** Aim to deliver an AI-driven, innovative, and technically strong product that demonstrates practical implementation of advanced AI techniques.
- **Supervisor:** Expects timely progress, technical correctness, and proper documentation of AI and ML methodologies.
- **Domain Expert:** Seeks accurate implementation of real-world exercise and diet rules to maintain professional credibility and health safety.
- **End Users:** Expect convenience, personalization, and safety while following adaptive fitness plans.
- **University:** Aims to encourage research-driven, market-relevant FYPs that showcase interdisciplinary applications of AI in health technology.

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3.7 Conclusion

This vision document outlines the purpose, direction, and scope of the Athletix project. It serves as a roadmap for achieving the goal of developing a robust, intelligent, and adaptive fitness application that leverages state-of-the-art AI technologies to promote healthier and more informed lifestyles.

Chapter 4

Software Requirements Specifications

This chapter will have the functional and non functional requirements of the project.

4.1 List of Features

4.2 Functional Requirements

4.3 Quality Attributes

4.4 Non-Functional Requirements

4.5 Use Cases/ Use Case Diagram

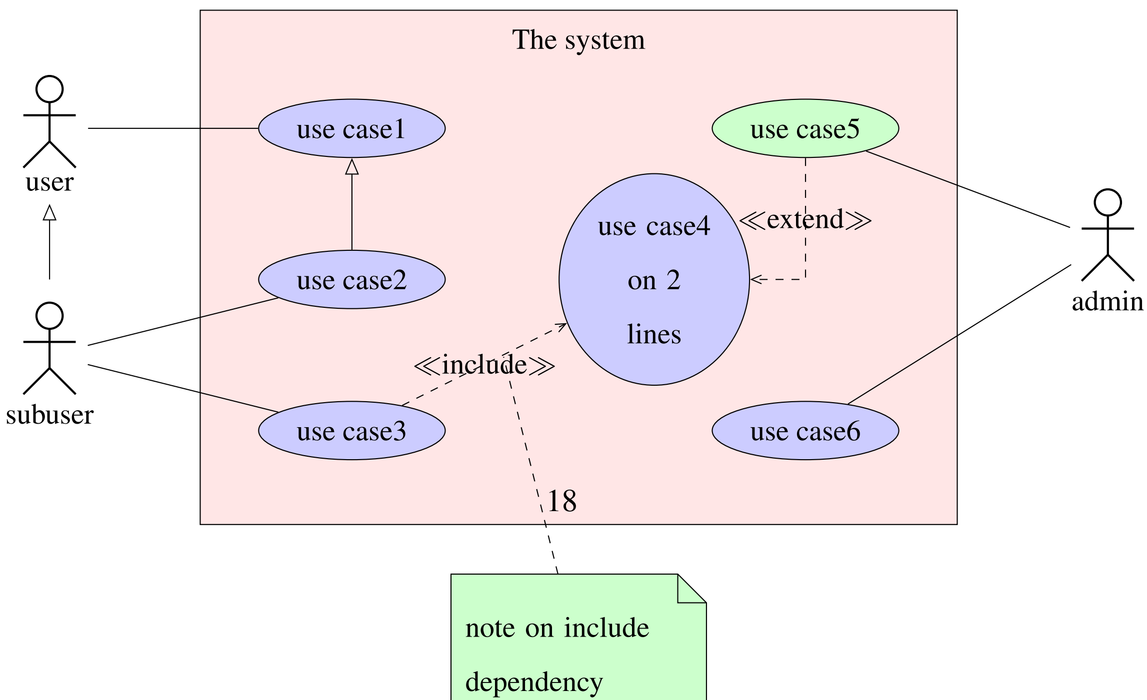
4.6 Sequence Diagrams/System Sequence Diagram

4.7 Test Plan (Test Level, Testing Techniques)

4.8 Software Development Plan

4.9 Wire-frames

4.10 UI Screens



Chapter 5

Iteration Plan

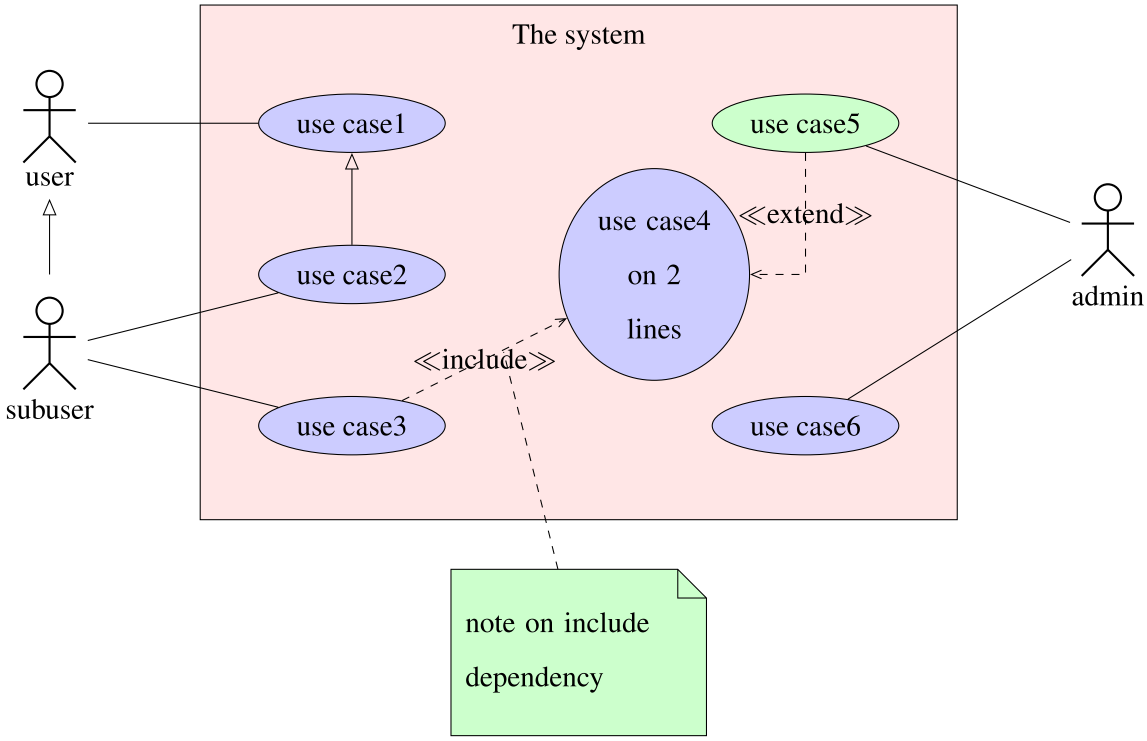
This chapter is used to describe the iteration plan of the project. How will try project proceeds to complete all the requirements. The chapter will guide about the modules of the project and development of those modules. In this chapter students are required to discuss the plan of execution of the project in terms of phases:

- Midterm FYP 1

- Final FYP 1

- Midterm FYP 2

- Final FYP 2


The system
use case1
use case5
user
use case4
on 2
lines
≪extend≫
admin
use case2
subuser
≪include≫
use case3
use case6
note on include
dependency

Chapter 6

Iteration 1

The first iteration is expected to be completed by the midterm of the FYP-1. This chapter will have some of the artifacts based on system design. The requirements analysis section is same for all the systems while the design may vary. There may have two types of designs the structural design or Behavior Design. First section is for the structural design.

structural design

6.1 Domain Model/ Class Diagram

6.2 Component Diagram

6.3 Layer Diagram

6.4 Structure Chart

Behavior Design

6.5 Flow Diagram

6.6 Data Flow Diagram (DFD)

6.7 Data Dictionary

6.8 Activity Diagram

6.9 Network Automata/ Graphs or State Machine

6.10 Call Graph or Sequence Diagram

6.11 Interaction Overview Diagram

For all above designs

6.12 Schema Design/ ER Diagram

6.13 Data Structure Design

Any information

6.14 Algorithm Design

Any information

6.15 Development Phase

Comments, Naming Conventions, Static Analysis of Code, etc.,

6.15.1 Unit Test

6.15.2 Suites or Test Cases

6.16 Maintainable Phase

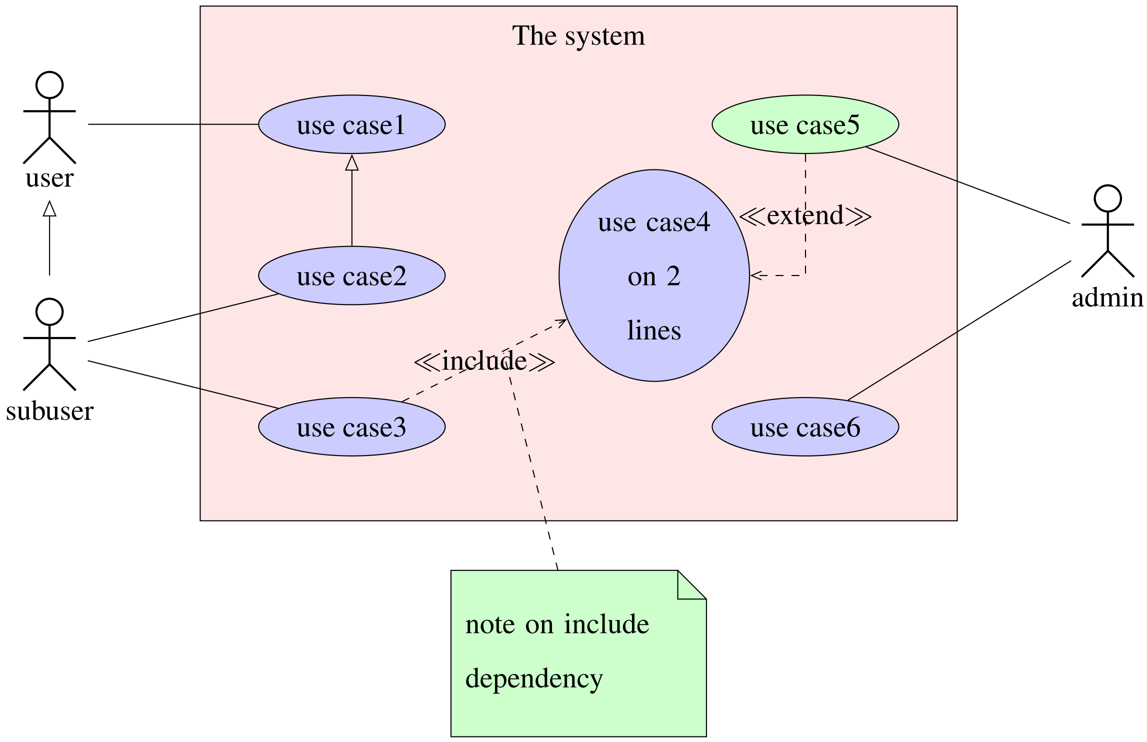
6.16.1 CI/ CD

6.16.2 Deployment Diagram

6.16.3 System-Level Test Suites, Test Cases

6.16.4 SVN or GitHub (Optional)

6.16.5 Configuration/ Setup and Tool Manual (Optional)



Chapter 7

Iteration 2

The first iteration is expected to be completed by the final of the FYP-1. This chapter will have some of the artifacts based on system design. The requirements analysis section is same for all the systems while the design may vary. There may have two types of designs the structural design or . First section is for the structural design.

structural design

7.1 Domain Model/ Class Diagram

7.2 Component Diagram

7.3 Layer Diagram

7.4 Structure Chart

Behavior Design

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7.7 Data Dictionary

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7.15 Development Phase

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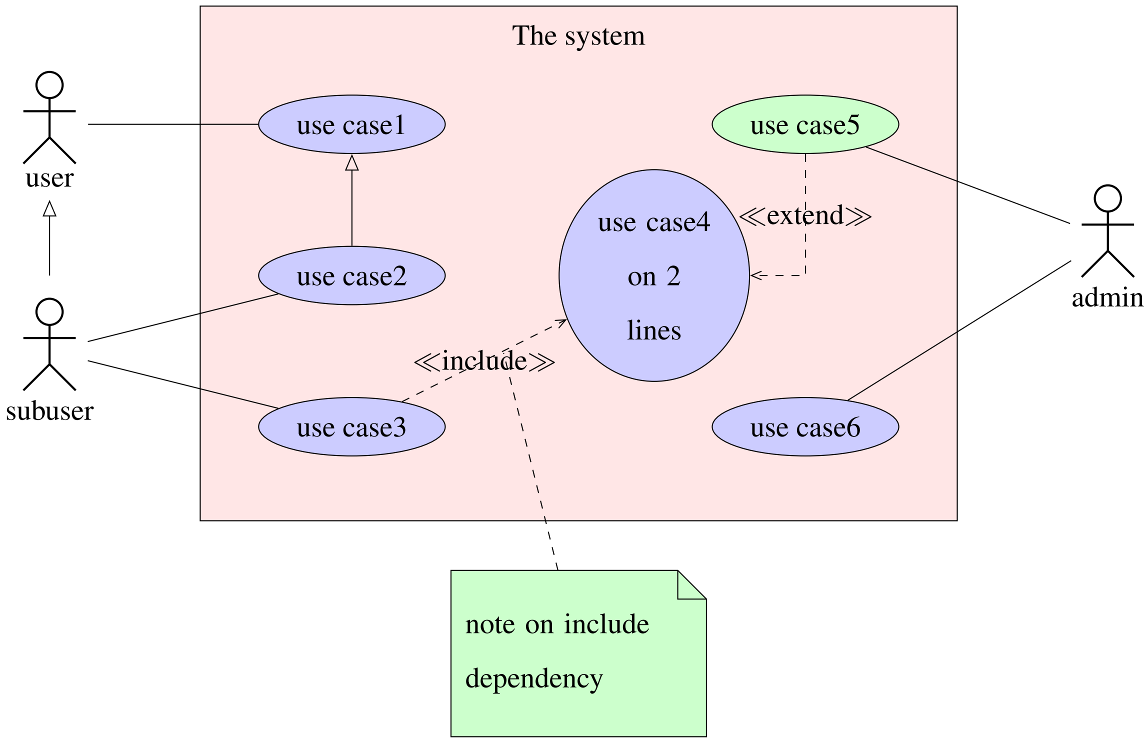
7.16.4 SVN or GitHub (Optional)

7.16.5 Configuration/ Setup and Tool Manual (Optional)



Chapter 8

Iteration 3

The first iteration is expected to be completed by the midterm of the FYP-2. This chapter will have some of the artifacts based on system design. The requirements analysis section is same for all the systems while the design may vary. There may have two types of designs the structural design or . First section is for the structural design.

structural design

8.1 Domain Model/ Class Diagram

8.2 Component Diagram

8.3 Layer Diagram

8.4 Structure Chart

Behavior Design

8.5 Flow Diagram

8.6 Data Flow Diagram (DFD)

8.7 Data Dictionary

8.8 Activity Diagram

8.9 Network Automata/ Graphs or State Machine

8.10 Call Graph or Sequence Diagram

8.11 Interaction Overview Diagram

For all above designs

8.12 Schema Design/ ER Diagram

8.13 Data Structure Design

Any information

8.14 Algorithm Design

Any information

8.15 Development Phase

Comments, Naming Conventions, Static Analysis of Code, etc.,

8.15.1 Unit Test

8.15.2 Suites or Test Cases

8.16 Maintainable Phase

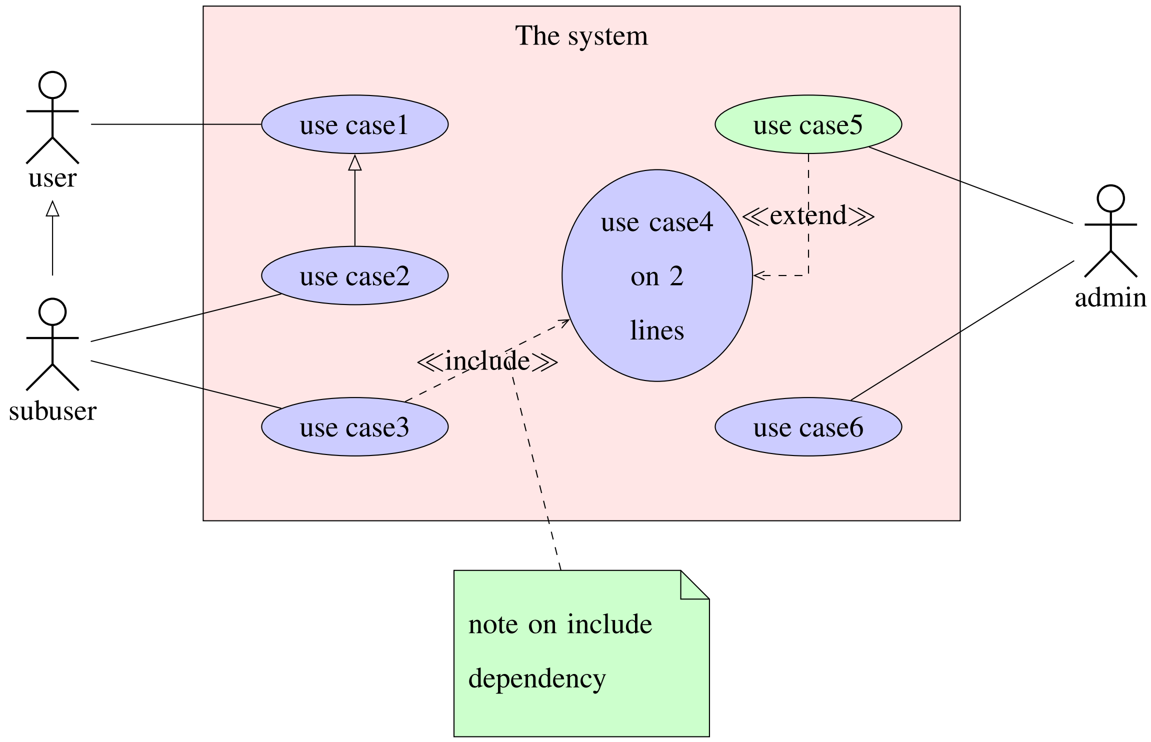
8.16.1 CI/ CD

8.16.2 Deployment Diagram

8.16.3 System-Level Test Suites, Test Cases

8.16.4 SVN or GitHub (Optional)

8.16.5 Configuration/ Setup and Tool Manual (Optional)



Chapter 9

Iteration 4

The first iteration is expected to be completed by the final of the FYP-2. This chapter will have some of the artifacts based on system design. The requirements analysis section is same for all the systems while the design may vary. There may have two types of designs the structural design or . First section is for the structural design.

structural design

9.1 Domain Model/ Class Diagram

9.2 Component Diagram

9.3 Layer Diagram

9.4 Structure Chart

Behavior Design

9.5 Flow Diagram

9.6 Data Flow Diagram (DFD)

9.7 Data Dictionary

9.8 Activity Diagram

9.9 Network Automata/ Graphs or State Machine

9.10 Call Graph or Sequence Diagram

9.11 Interaction Overview Diagram

For all above designs

9.12 Schema Design/ ER Diagram

9.13 Data Structure Design

Any information

9.14 Algorithm Design

Any information

9.15 Development Phase

Comments, Naming Conventions, Static Analysis of Code, etc.,

9.15.1 Unit Test

9.15.2 Suites or Test Cases

9.16 Maintainable Phase

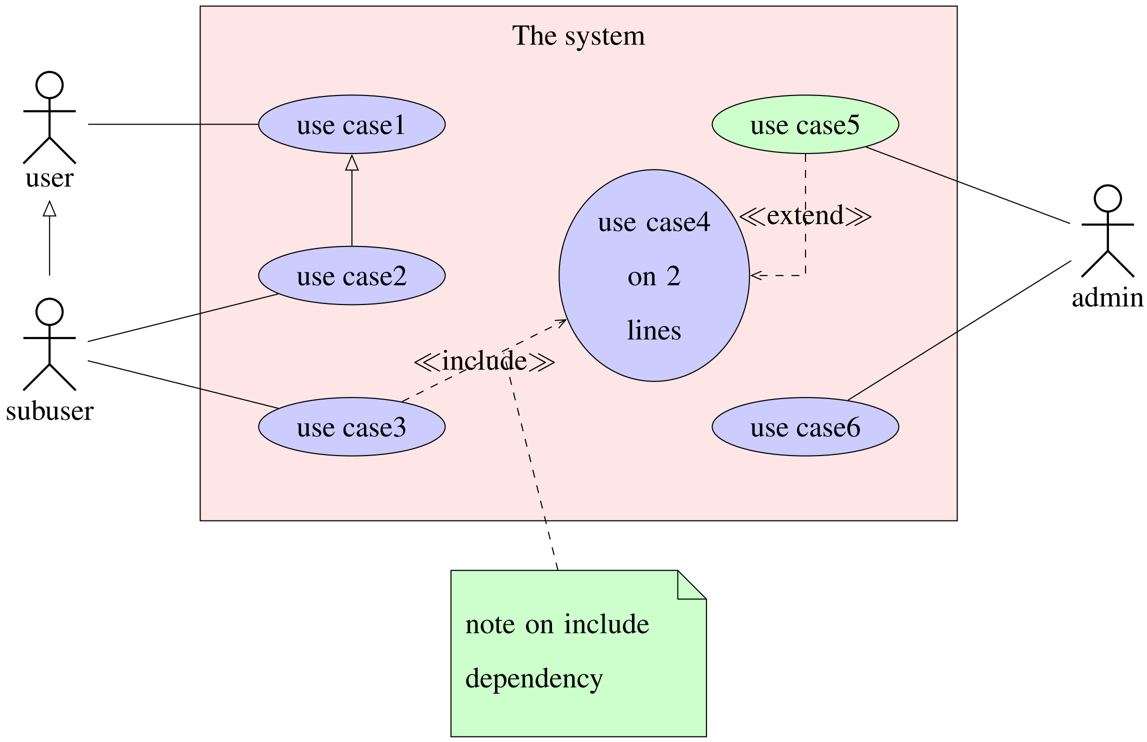
9.16.1 CI/ CD

9.16.2 Deployment Diagram

9.16.3 System-Level Test Suites, Test Cases

9.16.4 SVN or GitHub (Optional)

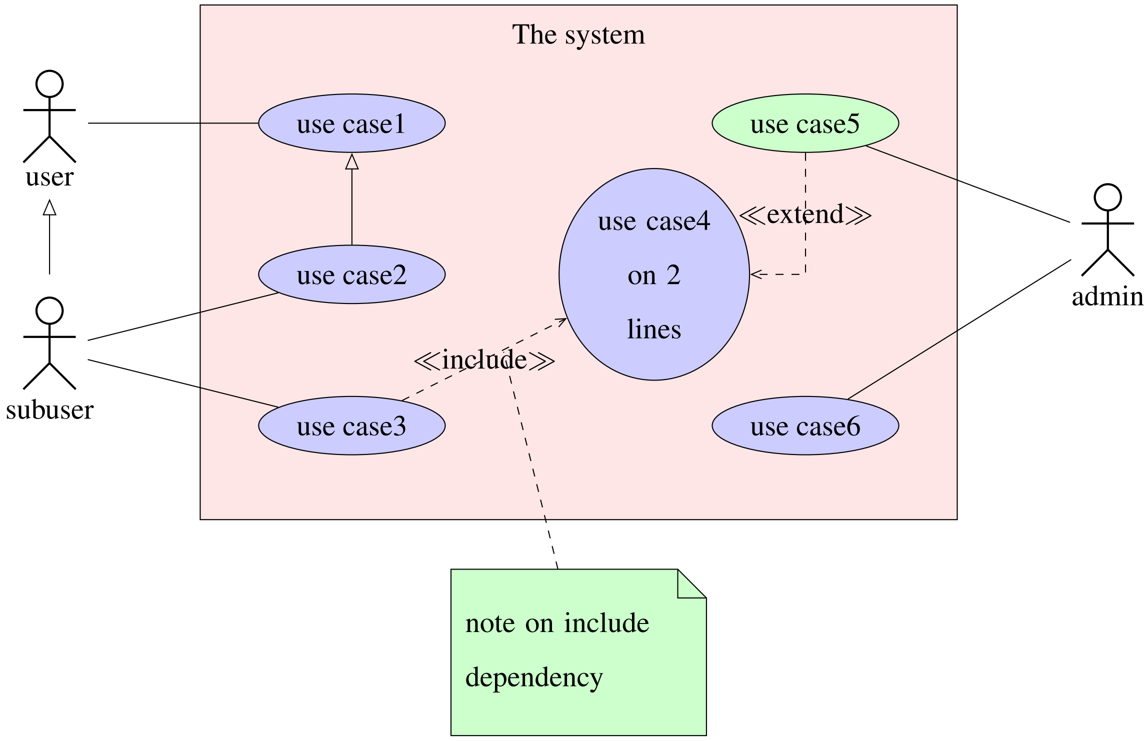
9.16.5 Configuration/ Setup and Tool Manual (Optional)



Chapter 10

Implementation Details

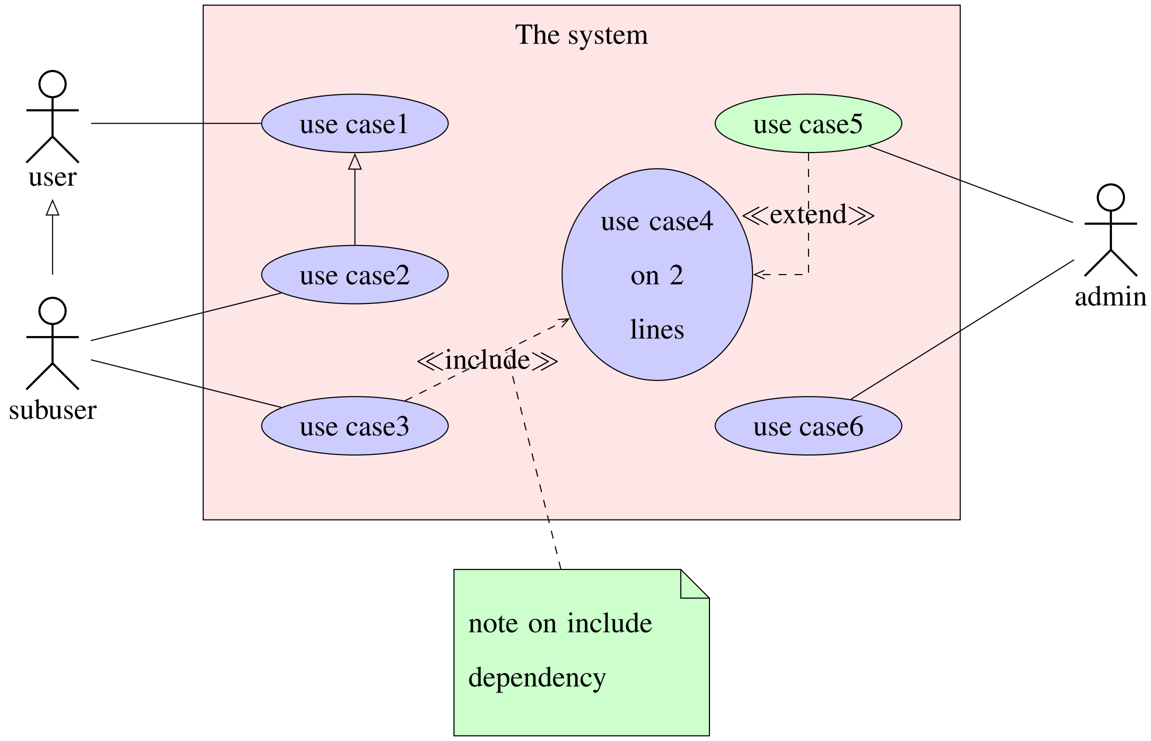
not the programming code but the algorithmic and procedural details especially related to the hidden/ backend algorithms that are not covered in the design



Chapter 11

User Manual

This chapter will have the user manual.



Chapter 12

Conclusions and Future Work

conclusions here

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