

Smart Barbell:

Software Requirements Specification

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(Based on IEEE SRS Standard)

(Specific Requirements organized by system feature)

1. Introduction

This section provides an overview of the entire software requirement specification of Smart Barbell.

1.1 Purpose

The purpose of this software requirement specification document is to describe the requirements specifications for Smart Barbell IoT System. Developers of team SEnSE, health center managers, and interested end-users are the intended audience of this software requirement specification document.

1.2 Scope

Smart Barbell is an IoT device provided with a web interface which helps people to be more concentrated and motivated to their workout. The Smart Barbell provides feedback on the user's workout in two ways; by real-time music feedback, and by record analysis after the workout. First, the Smart Barbell automatically changes the music based on the user's workout pace, calculated by lifts per minute, through the data retrieved from the sensor on the Barbell Device. With the workout data stored in the database, Smart Barbell also provides feedback and recommendation by analyzing and visualizing the workout history. Detailed information about the functionality will be provided throughout *2.Overall Description* and *3.Specific Requirements*.

With the described functionalities above, Smart Barbell will help users to continue exercise on a daily basis. We hope that Smart Barbell provides a new type of motivating factor to users - encouraging them to work out with their first resolutions.

1.3 Definitions, Acronyms, and Abbreviations

Term	Definition
Smart Barbell	Name of our software, or the entire system
SEnSE	Team Name: Software Engineering and Software Engineering
SRS	Software Requirements Specification
IoT	Internet of Things
Barbell Device	The IoT based barbell which could detect the motion of itself and transmits the motion data to the app server.

Workout	Activity of using the Barbell Device; lifting and lowering the barbell.
Workout User	Someone who interacts with the web page and does the workout using the Barbell Device.
Web page	A web application where the Workout User interacts with Smart Barbell and view the feedback on their workout.
Lift	A unit of the workout using the barbell. We call it a lift when the barbell rises from the lowest point to the highest point and then comes back to the lowest point.
top_timestamp	The time displacement from the start of the workout to the highest point.
bottom_timestamp	The time displacement from the start of the workout to the lowest point.
API	Application Programming Interface
AWS	Amazon Web Services
DBMS	Database Management System
Flask	Python Web Framework
HTTP	HyperText Transfer Protocol
REST	Representational State Transfer
Arduino	A microcontroller board
MPU-6050	Six-Axis (Gyro + Accelerometer) MEMS MotionTracking™ Device
ESP-8266	SOC with integrated TCP/IP protocol stack that provides a microcontroller access to the WiFi network

1.4 References

1. Altenmüller, E., & Schlaug, G. (2012). Music, brain, and health: exploring biological foundations of music's health effects. Music, health, and wellbeing, 12-24.

1.5 Overview

The remainder of this document includes the summary and detailed descriptions of the Smart Barbell.

In *2. Overall Description* is the overall explanation of the whole system. *2.1 Product Perspective* provides a broad understanding of the system, especially about the structure of the system and the relation with external systems. In 2.1.3 ~ 2.1.5 the hardware, software, and communication requirements are listed. In *2.2 Product functions*, the system features are introduced in the user's perspective, with use case diagrams. The functional requirements and use cases are listed in 2.2 but detailed descriptions are in *3. Specific Requirements*.

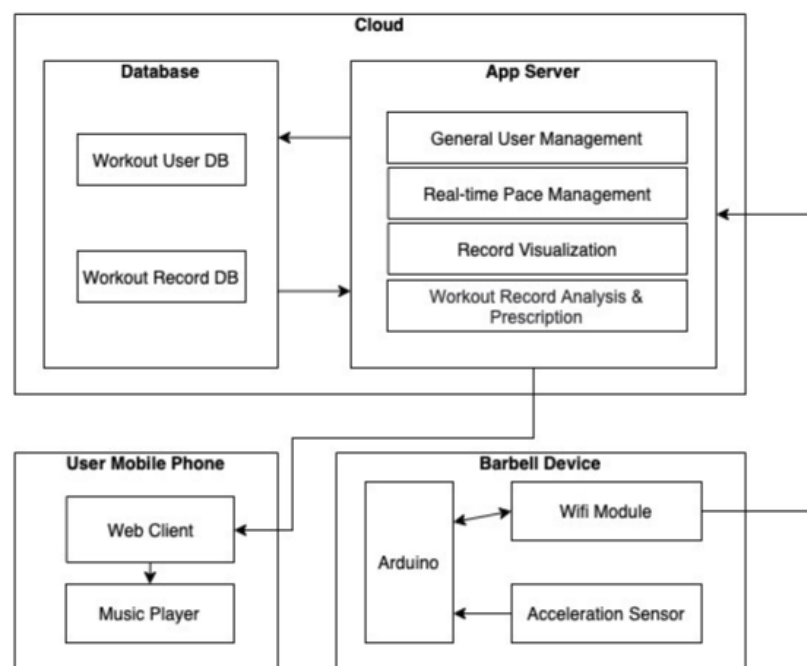
In *3. Specific Requirements*, the requirements listed in *2. Overall Description* are explained in detail, and following non-functional requirements are listed in 3.3 ~ 3.5.

2. Overall Description

2.1 Product perspective

2.1.1 System Interfaces

Following diagram is an overview of the whole Smart Barbell system.



[Figure 2.1: Block Diagram of Smart Barbell]

There are three big blocks that consist the whole Smart Barbell system – Cloud, Hardware (Smart Barbell Device), and User Mobile Phone. Cloud contains database and app server. There are two databases, Workout User DB and Workout Record DB. They store information of users, and workout record of every lift, respectively. App server has four features, and each feature will be described more specifically in 3.2. Barbell Device uses Arduino for processor, Wi-Fi module to connect internet,

and acceleration sensor to detect workout. User will access our web client by their mobile phone, and our service will open music player of their phone to play suggested music.

2.1.2 User Interfaces

The Workout User interacts with the Barbell Device by doing workout with it. All the controls are held in the user's mobile phone through a web page. In the web page, consists of a welcome page, profile page, barbell device control page, and record analysis page. Detailed explanations are in *3.1.1 User Interfaces*.

2.1.3 Hardware Interfaces

Code	Requirement Description	Priority
HIR-1	Barbell Device - Processor The Barbell Device shall be composed of a processor, Arduino Uno.	Critical
HIR-2	Barbell Device - Sensor MPU-6050 shall be used for the Barbell Device sensor.	Critical
HIR-3	Barbell Device - WiFi module ESP-8266 shall be used for the	Critical

2.1.4 Software Interfaces

Code	Requirement Description	Priority
SIR-1	Database Management System (DBMS) MySQL 8.0 shall be used as the database management system.	Critical
SIR-2	Operating System (Cloud OS) The cloud server shall have Linux (Ubuntu 20.04). IoT devices shall have no OS since they use simple microprocessors.	Critical
SIR-3	AWS Server The cloud server shall be driven by AWS server. This cloud server shall provide a web page to interact with users.	Critical
SIR-4	Web Service Next.js and Flask 2.1 with REST API shall be used for web service.	Critical
SIR-5	Data Transmission Format IoT device software will send a message of 'processed real-time sensor value' to Cloud Server in below format.	Critical

	[(top_timestamp, bottom_timestamp), ...]	
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2.1.5 Communication Interface

Code	Requirement Description	Priority
CIR-1	HTTP Protocol For communication, http shall be used as a protocol with REST API.	Critical

2.2 Product functions

In this section, we are going to first introduce a list of functional requirements. Then, four big systems of Smart Barbell will be introduced with user case diagrams.

Following is the list of functional requirements.

Code	Title	Requirement Description	Priority
FR-1	Create A New Account	A new work out user shall create a new account.	Critical
FR-2	Log In	A registered work out user shall get access to their account	Critical
FR-3	Manage Account Settings	A work out user shall change his/her account information, which is username and password. (Information such as weight, goal of exercising, etc. can be added).	Critical
FR-4	Manage System Settings	A system administrator should access all user accounts in order to prevent malicious users or dormant accounts.	Low
FR-5	Barbell Connection	The Barbell Device shall start its Real-Time Pace Management System when the user connects to the Barbell Device.	Critical
FR-6	Set Configuration	A work out user shall set the weight and target pace before starting a set, and also shall be able to change these information during the workout.	Critical
FR-7	Set Modification	When the user changes the set information, the system shall modify the values into the new ones.	Critical

FR-8	Lift Detection	The Barbell Device shall detect the lifts using the acceleration values retrieved from the accelerometer sensor.	Critical
FR-9	Data Transmission from Barbell Device to Cloud	The Barbell Device shall send request to the app server with top_timestamp and bottom_timestamp every time a lift is detected and the data shall instantly save to the DB with the user information.	Critical
FR-10	Pace Decision	The system shall be able to determine the Workout User's workout status by comparing the current pace to the target pace.	Critical
FR-11	Music Selection	The system shall select a corresponding music when the workout pace changes.	Critical
FR-12	Barbell Disconnection	The user shall be able to disconnect from the Barbell Device after the workout and	High
FR-13	Display Table	The system shall generate and display a table of workout indicators according to the date range.	Medium
FR-14	Display Graph	The system shall generate and display a line graph of workout indicators according to the date range.	High
FR-15	Display Pace	The system shall generate and display a pace log representing every lifts with its pace in sets and rest time.	Medium
FR-16	Retrieve Workout Records	The system shall query and retrieve the workout record with given range and filters.	High
FR-17	Share a Record to Social Media	The system shall share the specified record page utilizing platform-specific share methods.	Low
FR-18	Update Objective	A workout user shall select their objective between 'gain muscle', 'lose weight', and 'maintain health', and submit.	Medium
FR-19	Update Goal	A workout user shall enter a goal, related to their objective.	Medium
FR-20	Change Start Date	A workout user shall change the start date which will be used to calculate progress	High
FR-21	Check Latest Result	The system shall check if the latest analysis result stored in Workout User DB is up-to-date.	High
FR-22	Analyze Workout Record	The system shall analyze the workout record of the user. The result is composed of a welcome message, progress report, pace feedback, and workout prescription.	Critical

FR-23	Display Welcome Message	The system should display welcome messages on the main page, based on the analysis.	Medium
FR-24	Display Analysis Result	The system shall display analysis results, containing progress report, pace feedback, and workout prescription on the record analysis page.	Critical

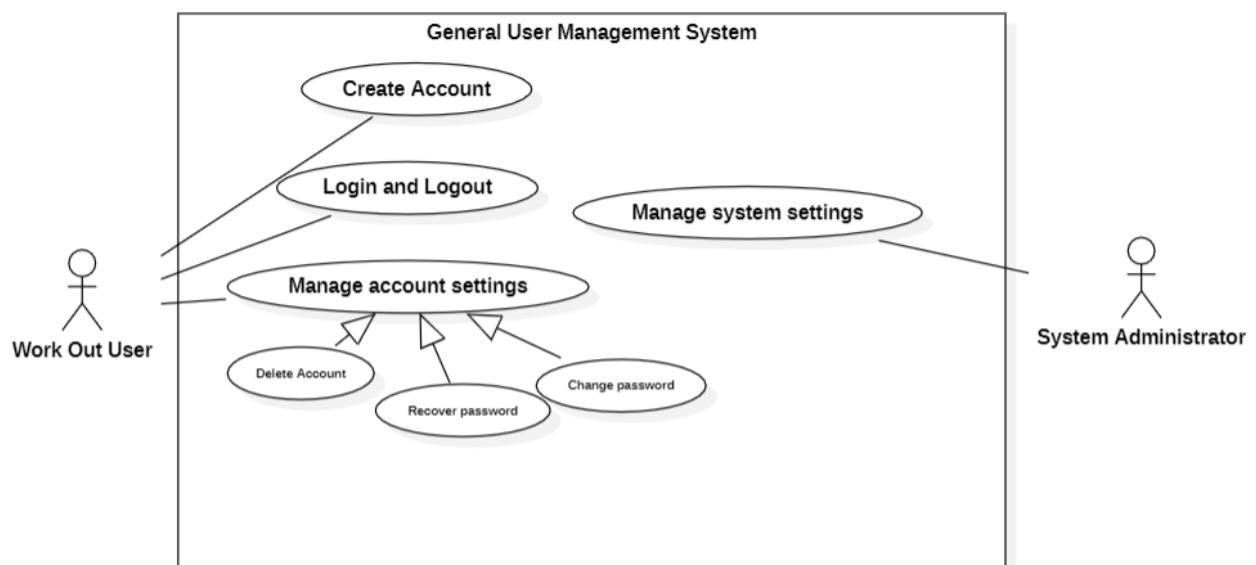
2.2.1 General User Management System

The General User Management system is in charge of managing new work out users and existing work out users for Smart Barbell to successfully get access to their account and exercise logs.

Description for the actors of this system feature is the following.

Workout User: Workout user enters required information for signing up or log in procedure. They also manage account settings, and this includes recovering the password, changing the password, and deleting an account.

System Administrator: System Administrator checks system settings and holds the ability to access any user in the system for possible security problems.



[Figure 2.2 General User Management System]

2.2.2 Real-Time Pace Management System

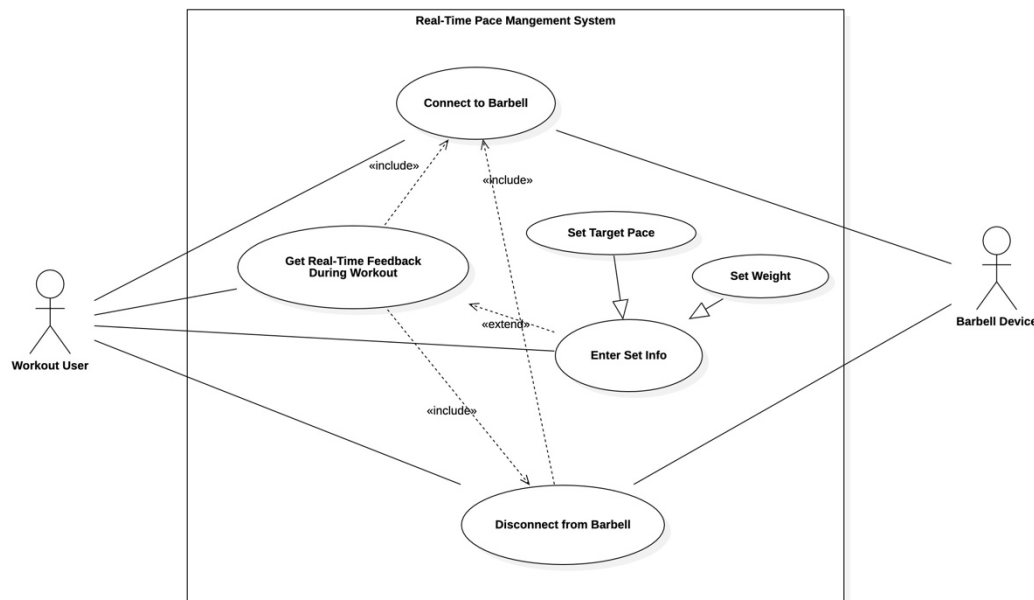
Real-Time Pace Management System starts from the user connecting to the Barbell. Throughout the whole process, the Barbell Device detects the movement of the Barbell and use it to analyze the workout status of the user. It compares the current workout pace of the user to the target pace.

Description for the actors of this system feature is the following.

Workout User: A Workout User is the end-user of our system. The Workout User uses the Barbell Device to do the workout and is willing to get feedback on their workout data. The Workout User initiates the system by connecting to the Barbell Device by web, and setting environments for the feedback. Then they receive real-

time feedback from the system and disconnects from the system after the workout is done.

Barbell Device: A Barbell Device is the main device of this system. This is an IoT device with an accelerometer/gyro sensor inside, and it is connected to the cloud server when the Workout User uses the device. This Arduino-based device gathers data with the sensor and processes it once before sending it to the cloud.



[Figure 2.3 Real-Time Pace Management System]

2.2.3 Record Visualization System

The Smart Barbell project's Record Visualization subsystem is designed to utilize measured real-time data and process it into various forms for future queries to provide convenience to the users. This extends the opportunity of motivation through workout records to those who work out in a light manner.

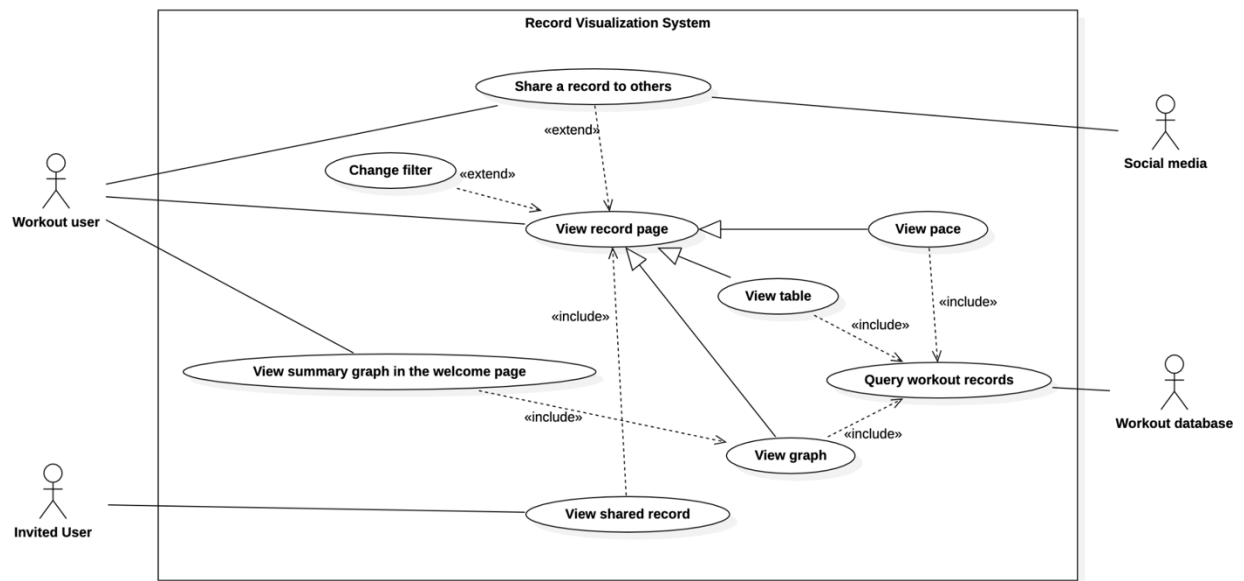
Description for the actors of this system feature is the following.

Workout User: Workout User is a user who requests the system to provide visualized data by choosing filters at their need and view the generated visualized records. The workout user is the only one who owns their records and has the right to request their data without restrictions.

Invited User: Invited User is a user who obtained the right to watch a part of the Workout User's record.

Workout Database (Workout DB): Workout Database is a long-term database stores records generated during the real-time workouts.

Social Media: Social Media is a platform-specific interface or a service used to send contents over social medias.



[Figure 2.4 Record Visualization System]

2.2.4 Workout Record Analysis & Prescription System

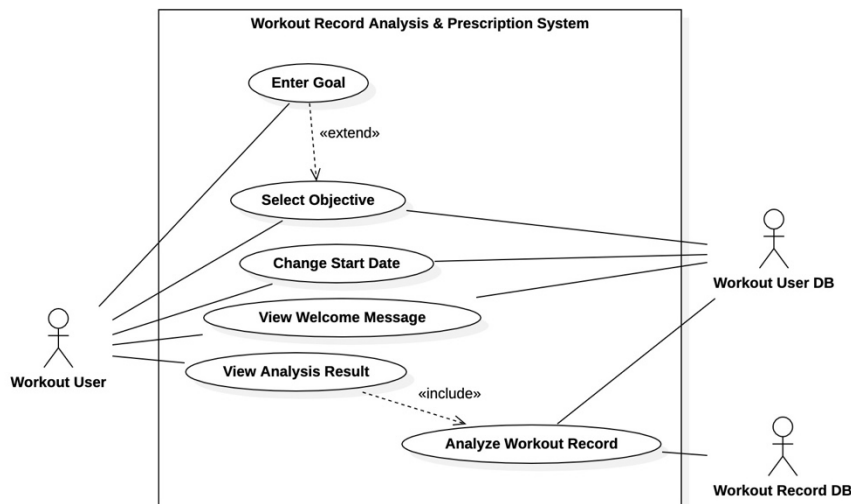
Workout Record Analysis and Prescription System provides analysis based on the user's objective. The Workout User shall select objectives between 'gain muscle', 'lose weight', and 'maintain health'. For each objective, there exists different goals that require the user to enter. The system will collect user's Workout Record form Workout Record DB, and save analysis results at Workout User DB.

Description for the actors of this system feature is the following.

Workout User : Person who registered to our system, using smart barbell services. Workout User shall select objectives and goals to get proper analysis results.

Workout User DB : Database containing the information of Workout User. For example, weight, height, objectives, goals, and analysis result are stored in this DB.

Workout Record DB : Database containing the workout record. Each row represents information of one lift. The system will analyze the workout record of the user collected from the Workout Record DB.



[Figure 2.5 Workout Record Analysis & Prescriptions System]

2.3 User characteristics

There are two types of users that interact with the system: users of the web application and administrator.

Web application users access the application when they start to work out. Then, Smart Barbell starts closely recording sensor data while the user is exercising. Since Smart Barbell is a device that is attached to a barbell, actual users of Smart Barbell are expected to have some experience in weight training or going to health centers.

Administrators manage the overall system and make sure that the system does not crash or fail by any reasons, such as unexpected behavior of a user, or an attack from malicious users. Administrators can have access to all system components, including database and web application.

2.4 Constraints

This section introduce how the whole Smart Barbell system works under various constraints. Types of constraints discussed here are software, hardware, and user interfaces.

Under software interfaces, the Smart Barbell should use enough computing power so that there are no much delay in processing Workout User's data. Also, whole system should be developed according to the hardware interfaces, since some hardware interfaces only supports specific programming language and commands. In this case, only C/C++ can be used to capture data and transfer it to the cloud in Arduino. The whole system is mostly event-driven, meaning that system is

determined by events such as user actions. Buttons and prompt in user interfaces will act to capture most of the events in the system.

2.5 Assumptions and dependencies

Some assumptions that are made while writing this document are the following.

1. Workout Users are expected to work out in internet-available places.
2. Workout Users are expected to know how to do a deadlift properly.

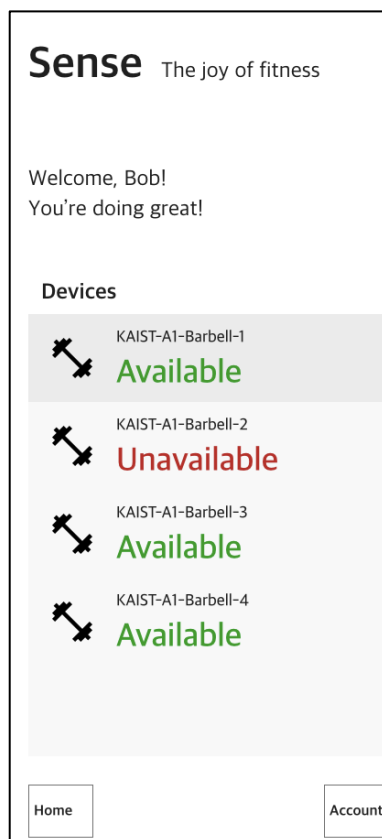
3. Specific Requirements

3.1 External interface requirements

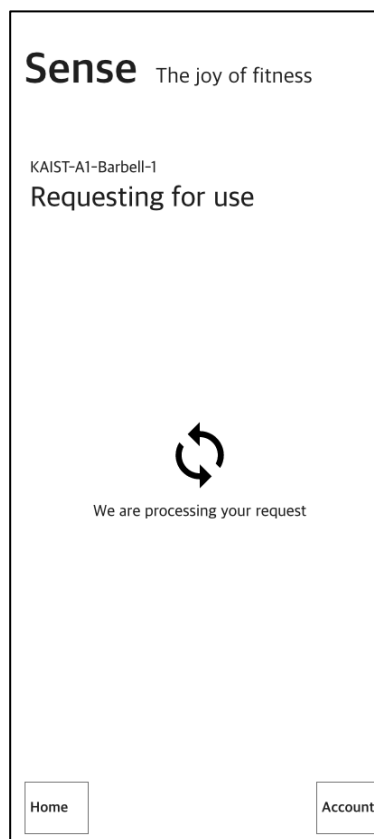
In this section, external interface requirements including user interface, hardware interface, and software interface will be introduced.

3.1.1 User Interfaces

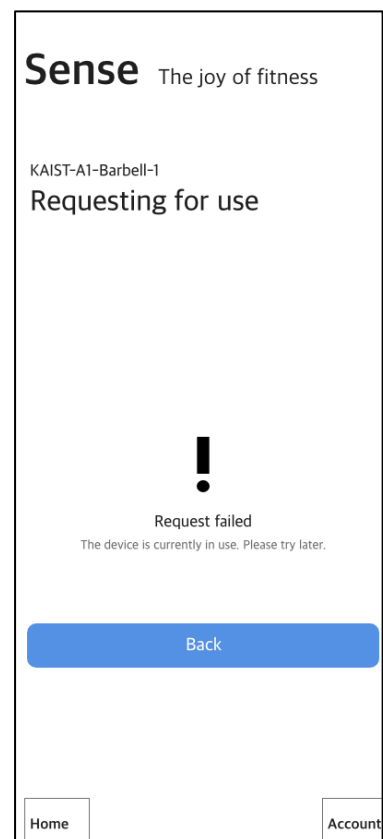
We have developed a prototype using Adobe XD. In this section, each screen will be introduced with a brief description to grasp the overall theme of the user interfaces of Smart Barbell.



[Figure 3.1: Dashboard]



[Figure 3.2: Request Connection]



[Figure 3.3: Connection Failed]

3.1.1.1 Dashboard

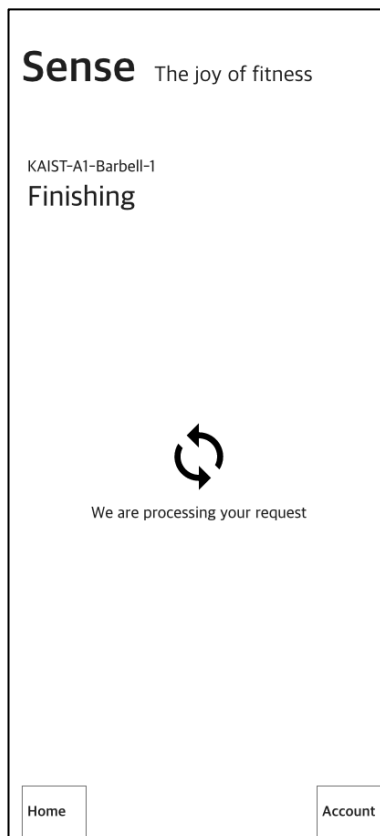
Signed users should see the dashboard. In the dashboard, users can see recently used devices and their availability. If the user is not signed in, the user should see the sign-in page. Users can move to the account registration page. Every user can see their account info in the account page. The user can change the password in the account page.

3.1.1.2 Request Connection

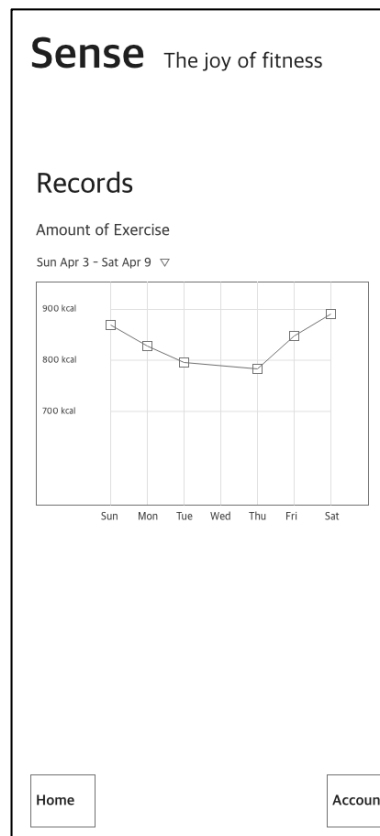
When Workout User clicks a barbell to connect, following screen is loaded.

3.1.1.3 Connection Failed

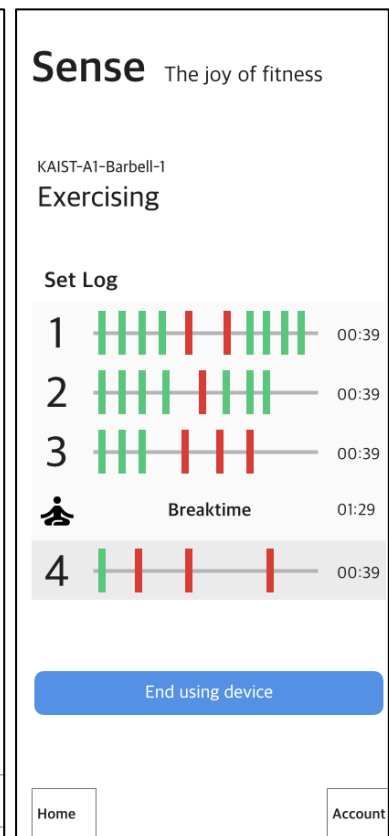
Workout User fails to connect to a Barbell, following screen is loaded.



[Figure 3.4: Terminate Connection]



[Figure 3.5: Workout Graph]



[Figure 3.6: Workout Pace]

3.1.1.4 Terminate Connection

When Workout User finishes using a Barbell and click on End Using Device Button, following screen is loaded.

3.1.1.5 Workout Graph

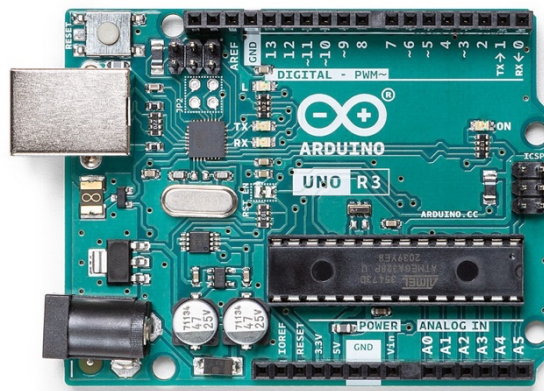
When Workout User wants to see the record for the workout, which is possibly right after the work out, Workout User should navigate to the record page and enter the analysis type. Then, the following screen is loaded.

3.1.1.6 Workout Pace

Workout Users can check their pace throughout the pace. Each line shows the time each lift was done. Red lines indicate the lifts when the pace got slower, and green lines indicate the lifts with appropriate pace.

3.1.2 Hardware Interfaces

HIR-1: IoT Device - Processor



[Figure 3.7: Arduino Uno Rev3]

Arduino Uno Rev3 will be used as the processor of our IoT Device. It is microcontroller based on the ATmega328P. It has 14 digital input/output pins and requires 6-20V of input voltage.

HIR-2: IoT Device – Sensor

MPU-6050 will be used as the sensor of our IoT Device. It is a 6-axis motion tracking device consisting of 3-axis accelerometer and 3-axis gyroscope interfacing with Arduino processor with the I2C module. We use the Kalman Filter to measure the displacement of the Barbell Device.

Features	Gyro Full Scale Range (°/sec)	Gyro Sensitivity (LSB°/sec)	Gyro Rate Noise (mdps/rHz)	Accel Full Scale Range (g)	Accel Sensitivity (LSB/g)	Digital Output	Operating Voltage Supply	Package Size (mm)
Value	±250 ±500 ±1000 ±2000	131 65.5 32.8 16.4	0.005 0.005 0.005 0.005	±2 ±4 ±8 ±16	16384 8192 4096 2048	I2C	2.375V– 3.46V	4x4x0.9

[Figure 3.8: MPU-6050 Specification]

HIR-3: Barbell Device – WiFi module

ESP8266-01 will be used for the WiFi module of our IoT Device. The ESP-01 has four GPIO pins that can be used to read external sensor signals.

- Operating voltage: 3.3V
- WIFI Support Specification: 802.11b/g/n
- Wi-Fi Direct (P2P), soft-AP both available
- 802.11b reference output is +19.5 dBm
- Built-in antenna on board, external antenna connection possible
- Available temperature range: -40°C to 125°C
- Low power 32-bit CPU, built-in 10-bit ADC
- SDIO 2.0, SPI, UART, STBC, 1×1 MIMO, 2×1 MIMO available

3.1.3 Software Interfaces

SIR-1 : Database Management System (DBMS)

MySQL 8.0 shall be used as the database management system.

SIR-2 : Operating System (Cloud OS)

The cloud server shall have Linux (Ubuntu 20.04), with x86-64bit architecture. IoT devices shall have no OS since they use simple microprocessors.

SIR-3 : Cloud Server – AWS server

Amazon EC2 instance is used for the server side in this project. More specifically, general purpose – t2.micro will be used. Systems shown in [Figure 2.1] will be implemented and run here.

SIR-4 : Web Service

Next.js and Flask 2.1 with REST API shall be used for web service. The website will be published using Github Pages, with a domain .github.io.

SIR-5 : Data Transmission Format

HTTP connection between IoT device and the cloud server will be activated when the data is transmitted. IoT device software will send a message of 'processed real-time sensor value' to Cloud Server in the format explained in *2.1.4 Software Interfaces*.

3.1.4 Communications Interfaces

CIR-1 : HTTP Network

All communication of the system is done by internet connection with HTTP. No local network will be required.

3.2 System features

This section contains all of the software requirements to a level of detail sufficient to enable designers to design a whole Smart Barbell system, including functional requirements, non-functional requirements, and other requirements. Use case description is given with a table to implicitly show the application of each functional requirements.

3.2.1 General User Management

This part introduces the general feature of user management in the Smart Barbell. The purpose of these features is to prepare an environment for users before working out and using the functionalities of Smart Barbell.

A set of the features for General User Management is used when a user starts to use Smart Barbell.

Below are possible use case descriptions.

3.2.1.1 Create a New Account

Use case name	Create a New Account	
Related Requirements	FR-1, PR-2, PR-6, SNFR-2, RNFR-1	
Goal In Context	A new Workout user creates a new account.	
Preconditions	None	
Successful End Condition	A new account is created for the Workout user.	
Failed End Condition	Account creation is failed, or denied.	
Primary Actors	User	
Secondary Actors	None	
Trigger	Workout Users click on the register button on the home screen.	
Main Flow	Step	Action
	1	The Workout user enters the required information values and requests for a new account.
	2	The system validates the entered information.
	3	The values of information are stored in the Workout user's account. The system notifies the user about the account creation.

Extensions	Step	Branching Action
	2.1	If the username already exists, account creation is denied.

3.2.1.2 Log In

Use case name	Log In	
Related Requirements	FR-2, PR-3, SNFR-2, RNFR-1	
Goal In Context	A registered user gets access to their account.	
Preconditions	User account should be created in <i>Create a New Account</i>	
Successful End Condition	Users are accessible to their account.	
Failed End Condition	User access to the account is denied, or failed.	
Primary Actors	User	
Secondary Actors	None	
Trigger	Initial screen shows the LogIn Screen to users.	
Main Flow	Step	Action
	1	The system shall display the LogIn Screen.
	2	User enters account information, username and password, created in <i>Create a New Account</i> .
	3	The values of information are verified with the one in the user account database, (or credentials database). Access is granted to the user if the information matches.
Extensions	Step	Branching Action
	3.1	If the entered information does not match to the one in the user account database, notify the user about log in failure.

3.2.1.3 Manage Account Settings

Use case name	Manage Account Settings
Related Requirements	FR-3, SNFR-2
Goal In Context	A Workout User can change his/her account information, which

	is username and password. (Information such as weight, goal of exercising, etc can be added).	
Preconditions	Workout User accounts should be created in <i>Create a New Account</i> . Users should be logged in to their account.	
Successful End Condition	Workout User account information is successfully changed.	
Failed End Condition	Workout User account information is not changed.	
Primary Actors	Workout User	
Secondary Actors	None	
Trigger	Workout Users click on manage account settings on the home screen.	
Main Flow	Step	Action
	1	The system shall display the Home Screen.
	2	Workout User clicks on manage account settings.
	3	The system shall display the list of user information.
	4	Workout Users can click on each section of the information and change it.
	5	Workout Users click on the save button on the bottom.
	6	The system shall apply the changes done to the user account database.
Extensions	Step	Branching Action
	6.1	Change is not applied due to duplicate username.

3.2.1.4 Manage system settings

Use case name	Manage System Settings
Related Requirements	FR-4, SNFR-2
Goal In Context	A system administrator can access all user accounts in order to prevent malicious users or dormant accounts.
Preconditions	System administrator account should exist.
Successful End Condition	System administrator access to user accounts.

Failed End Condition	Workout User account access denied, or failed.	
Primary Actors	System administrator	
Secondary Actors	None	
Trigger	System administrator log in.	
Main Flow	Step	Action
	1	The system shall display the Log In Screen.
	2	The system administrator enters account information, username and password.
	3	The values of information are verified with the one in the user account database, (or credentials database). Access is granted to the user if the information matches.
	4	The system shall display Administrator Screen.
	5	System Administrator clicks on a user in the user list.
	6	System Administrator can manage that user's account settings.
Extensions	Step	Branching Action
	3.1	Information mismatch; Same flow with <i>Log In</i>

3.2.1.5 Associated Functional Requirements

FR-1: Create a New Account

Input: User name, user height, user weight (information entered by the user)

Process:

1. The system shall get the input from a new work out user.
2. The system shall check if the username from information is already taken or not.
If is taken, notify user about it and go back to 1. If not taken, proceed to 3.
3. The system shall save the specific information in the Workout User DB.
4. The system shall notify user about the account creation.
5. The system shall then display Log In Screen.

Output: User ID (new account saved in Workout User DB)

FR-2: Log In

Input: User ID (login information entered by a Workout User)

Process:

1. The system shall get the input from a new workout User.

2. The system shall validate if the entered information matches the one in the Workout User DB. If not matches, notify the user about it and go back to 1. If matches, proceed to 3
3. The system shall display dashboard.

Output: Success/Fail (access to Smart Barbell system)

FR-3: Manage Account Settings

Input: Click on Account button by a Workout User.

Process:

1. The system shall load the information about account creation from Workout User DB.
2. The system shall be able to get input from Workout user about different sections of account information, such as username, password, and etc (Can be extended to age, weight, and other health-related information).
3. The system shall overwrite the entered information from 2 to the Workout User DB.
4. The system shall notify when account information is changed.

Output: (Possibly) Changed information is applied to a Workout User's account.

FR-4: Manage System Settings

Input: User ID (login information entered by a system administrator.)

Process:

1. The system shall get the input from the system administrator.
2. The system shall validate if the entered information matches the one in the Workout User DB. If not matches, notify the user about it and go back to 1. If matches, and the account is for the system administrator, proceed to 3. If the account is for normal Workout User, it is handled in FR-2.
3. The system shall display system administrator screen.
4. The system shall give the authority to any Workout User's account information to the system administrator.

Output: Success/Fail (System Administrator authorized)

3.2.2 Real-time Pace Management

During the workout, the Real-Time Pace Management system provides the Workout User Real-Time Feedback on their workout status based on their pace. The song will change depending on the workout status as a result. With the data provided from the Barbell Device, the Workout Analyzing System compares the current Workout User's pace to the target pace. If the current pace is too slower than the target, the system will change to an exciting music.

3.2.2.1 Connect to Barbell

Use Case Name	Connect to Barbell	
Related Requirements	FR-5, PR-1, PR-7	
Goal in Context	A Workout User connects to the Smart Barbell before their workout so that the system can analyze the workout data.	
Preconditions	1. A Workout User has already signed up to the web page. 2. A Workout User has a QR code recognition application in their phone.	
Successful End Condition	The webpage shows “Enter Set Info” page to A Workout User.	
Failed End Condition	The webpage doesn’t show the “Enter Set Info” page.	
Primary Actors	Workout User, Barbell Device	
Secondary Actors	None	
Trigger	A Workout User scans the QR code on the Smart Barbell.	
Main Flow	Step	Action
	1	A Workout User scans the QR code that leads to the webpage.
	2	The page shows the confirmation page with information about the barbell.
	3	A Workout User selects the “Select this Barbell” button.
	4	The page shows the “Enter Set Info” page.
Extensions	Step	Branching Action
	1.1	A Workout User isn’t logged in to the web page.
	1.2	The page shows the login page.
	1.3	A Workout User logs into the webpage, then it shows the confirmation page.
	3.1	A Workout User is already connected to another device.
	3.2	The webpage asks the user whether to “disconnect from the previous device?”.
	3.3	If the user selects “Yes”, show the confirmation page of step 2. If the user selects “No”, inform them that the user cannot connect to the current device before disconnecting from the previous device.

3.2.2.2 Enter Set Info

Use Case Name	Enter Set Info	
Related Requirements	FR-6, FR-7, PR-7	
Goal in Context	A Workout User sets the weight and target pace before starting a set.	
Preconditions	A Workout User is connected to the Barbell Device.	
Successful End Condition	The webpage shows the popup to tell that the change has successfully been saved.	
Failed End Condition	The webpage doesn't show the change success popup.	
Primary Actors	Workout User	
Secondary Actors	None	
Trigger	A Workout User presses the "Change the Set Info" button once.	
Main Flow	Step	Action
	1	The Enter Set Info page shows the default weight and target pace.
	2	A Workout User enters the number for the weight and target pace.
	3	A Workout User selects the "Set the Set Info" button.
	4	The page shows the popup message that informs A Workout User that the set info has successfully changed.
	5	The Enter Set Info page shows the changed weight and target pace.
Extensions	Step	Branching Action
	1.1	The user has already configured the set information before.
	1.2	The Enter Set Info page shows the previous weight and target pace.
	2.1-a	The input number is invalid. (It is out of range)
	2.2-a	The value is set to either the maximum or the minimum value.
	2.1-b	A Workout User might not want to set the target pace.
	2.2-b	A Workout User selects "Free" button for the target pace input.

3.2.2.3 Disconnect from Barbell

Use Case Name	Disconnect from Barbell	
Related Requirements	FR-12, PR-7	
Goal in Context	The Workout User changes the weight / target pace so that the system will give feedback with the new information.	
Preconditions	1. A Workout User is connected to the Barbell Device. 2. A Workout User has his Enter Set Info page open.	
Successful End Condition	The web page shows the popup to tell that the change has successfully been saved.	
Failed End Condition	The web page doesn't show the change success popup.	
Primary Actors	Workout User	
Secondary Actors	None	
Trigger	A Workout User presses the "Change Set Info" button once.	
Main Flow	Step	Action
	1	The Enter Set Info page shows the current weight and target pace.
	2	A Workout User enters the number for the weight and target pace.
	3	A Workout User selects the "Change Set Info" button.
	4	The page shows the popup message that informs A Workout User that the set info has successfully changed.
	5	The Enter Set Info page shows the changed weight and target pace.
Extensions	Step	Branching Action
	2.1-a	The input number is invalid. (It is out of range)
	2.2-a	The value is set to either the maximum or the minimum value.
	2.1-b	A Work Out doesn't want to set the target pace.
	2.2-b	A Workout User selects the "Free" button for the target pace input.

3.2.2.4 Get Real-Time Feedback during Workout

Use Case Name	Get Real-Time Feedback during Workout	
Related Requirements	FR-8, FR-9, FR-10, FR-11, RNFR-2, RNFR-3	
Goal in Context	The Workout User wants to get real-time feedback on their workout as he lifts the barbell.	
Preconditions	There is a preset playlist in the app server with labels('Exciting', 'Neutral', 'Calm') on it.	
Successful End Condition	The system changes to an exciting song when the user's pace becomes slower than the target pace.	
Failed End Condition	The system doesn't change the song even when the user's pace becomes slower than the target pace.	
Primary Actors	Workout User	
Secondary Actors	Barbell Device	
Trigger	The lifting speed of the Workout User Gets slower.	
Main Flow	Step	Action
	1	The user lifts the barbell slower than the target pace.
	2	The system detects that the user is slower than the target pace.
	3	The music changes to an exciting music in the web page of the user's mobile phone.
Extensions	Step	Branching Action
	2.1-a	The workout pace of the user was appropriate.
	2.2-a	The system plays a random song from the playlist for the next song.
	2.1-b	A Work Out doesn't want to set the target pace.
	2.2-b	A Workout User selects the "Free" button for the target pace input.

3.2.2.5 Associated Functional Requirements

FR-5: Connect to Barbell

When the Workout User presses the "Select this Barbell" button, the user's mobile phone shall send a request to the app server with the user ID and check whether is user is already connected to another barbell.

Input: Workout User ID

Process:

1. The app server receives the user ID from request.

2. The app server checks the Workout User DB if the user has been connected to another barbell already.
3. If the user's current connection state is 'disconnected', change to 'connected'.
4. Request the Barbell Device to start its detection.

Output: Success/Fail

Alternative Flow:

- 3.1 The user's current connection state is 'connected'
- 3.2 Display a popup message asking "disconnect from the previous device?"
- 3.3 When the user confirms the message, change the current connection state to 'disconnected'
- 3.4 Move on to Process-4

FR-6, 7: Set Configuration, Set Modification

When the Workout User presses the "Change Set Info" button, the user's mobile shall send a request to the app server with the new set information. After then, the system shall compare the current pace with the new set information.

Input: Weight, Target Pace

Process:

1. The app server receives request from the mobile phone with new weight and target pace.
2. Replace the previous weight and target pace with the new values.
3. Send request back to the mobile phone that the set information has successfully been configured.

Output: Success/Fail

FR-8: Lift Detection

When the Workout User presses the "Change Set Info" button, the user's mobile shall send a request to the app server with the new set information. After then, the system shall compare the current pace with the new set information.

Input: Raw data (3 accelerometer values, 3 gyroscope values)

Source: MPU-6050 sensor

Process:

1. When the
2. The Barbell Device applies a Kalman filter to the raw data.
3. The Barbell Device detects the position and velocity of the Barbell Device.
4. When the velocity is 0, the Barbell Device decides that the device has reached a top point or a bottom point.
5. Whenever the Barbell Device reaches the bottom point, it shall send a request to the ap server with the timestamp.

Output: top_timestamp, bottom_timestamp

Destination: App server

FR-9: Data Transmission from Barbell Device to Cloud

When a lift is detected, the app server receives the timestamp from the Barbell Device. Then, the app server shall save the lift information with the top_timestamp, bottom_timestamp and the current workout user information.

Input: top_timestamp, bottom_timestamp, user id

Source: Barbell Device

Process:

1. The app server receives a request from the Barbell Device after a lift.
2. The app server saves the top_timestamp and bottom_timestamp to the MySQL datatable with the user id

Output: Success/Fail

Destination: Workout Record DB

FR-10: Pace Decision

When a lift is detected and the app server receives the timestamp, it shall compare it to the target pace.

Input: top_timestamp, bottom_timestamp, target pace

Source: Barbell Device, App Server

Process:

1. The app server receives a request from the Barbell Device after a lift.
2. The app server retrieves the target pace received from FR-7.
3. Compare the target pace to the time gap between the top_timestamp and the bottom_timestamp.
4. If the target pace value is smaller than the time gap, return "Slow"
- 4.1 If the target pace value is larger than the time gap, return "Okay"

Output: Slow/Okay

Destination: Music Selection Function (FR-11)

FR-10: Music Selection

Depending on the Pace Decision result, the system shall select a corresponding music. If the current pace is slower than the target pace, the system shall change to an "exciting" song, and if not, play a random song.

Precondition: App server has a list of songs labeled by "exciting", "neutral", and "calm"

Input: Slow/Okay (result of FR-10: Pace Decision)

Process:

1. Check the result of pace decision.
2. If the result is "Slow", look up for a song in the "exciting" list.
3. Play the first song in the "exciting" list.
4. Move the first song to the last part of the list.

Alternative Flow:

2. If the result is "Okay", look up for a song in the original list.

3. Play the first song in the list.
 4. Move the first song to the last part of the list.
- Output: Success/Fail

FR-12: Barbell Disconnection

When the user finishes the workout, they could select a “Disconnect” button in their mobile phone. Then the mobile phone and the Barbell Device shall be disconnected from the app server.

Input: Button press (“Disconnect” button pressed in the mobile phone)

Process:

1. Disconnect button is pressed by the Workout User.
2. The mobile phone sends a request to the app server to disconnect.
3. The app server deletes the weight and target information.
4. The app server orders the Barbell Device to stop the detection.

Output: Success/Fail

3.2.3 Record Visualization

Record Visualization subsystem retrieves data such as the number of sets, speed, time, and weight measured and stored through sensors connected to the IoT device and provides it to the user as a visual representation. This includes tables and several types of graphs. Users can query the data measured over the desired time period in several criteria or methods. However, the subsystem focuses on querying and effectively visualizing data, it is not the subsystem's role to analyze the data and provide meaningful insights and feedback to the user.

The features for the record visualization system starts when the user requests visualized records to the system.

3.2.3.1 View Record Page

Use case name	View Record Page
Related Requirements	FR-13, FR-14, FR-15, FR-16
Goal In Context	A workout user views their records in the “record” page.
Preconditions	None
Successful End Condition	A workout record requested is displayed.
Failed End Condition	The web page doesn't display the record.
Primary Actors	Workout User
Secondary Actors	None

Trigger	A Workout User accesses the record page.	
Main Flow	Step	Action
	1	The Workout User enters the “records” page.
	2	The system displays a list of visualization methods: table and graph.
	3	The Workout User selects “table” from the visualization methods.
	4	The system displays the workout table with this week’s daily workout records.
	5	The Workout User selects “change filter” button.
	6	The system displays a list of available filter options.
	7	The Workout User selects “total lifts” from the indicators.
	8	The Workout User selects “apply” button.
	9	The system displays New table with additional “total lifts” indicator.
Extensions	Step	Branching Action
	4.1-a	There isn’t any workout record queried from the database.
	4.2-a	The system notifies the user no data is available.
	4.1-b	The user authentication failed.
	4.2-b	The system notifies the user not enough permission.

3.2.3.2 Share a record to others

Use case name	Share a record to others
Related Requirements	FR-17
Goal In Context	A workout user shares their record displayed in the “record” page.
Preconditions	A workout record is displayed.
Successful End Condition	A URI links workout record is delivered to the social media.
Failed End Condition	There is no social media available for sharing. The sharing is canceled since the record is expired.

Primary Actors	Workout User	
Secondary Actors	Social Media	
Trigger	A Workout User selects share button on the “record” page.	
Main Flow	Step	Action
	1	The workout user selects “share” button .
	2	The system displays lists of social medias provided by the platform.
	3	The workout user selects the social media and the target.
	4	The system generates a link to the page and send it to the target.
Extensions	Step	Branching Action
	3.1-a	There is no social media available.
	3.2-b	The Workout User cancels sharing.

3.2.3.3 View summary graph in the welcome page

Use case name	View summary graph in the welcome page	
Related Requirements	FR-14, FR-16	
Goal In Context	The Workout User watches their record in the form of graph in the welcome page.	
Preconditions	The Workout User is logged in the system.	
Successful End Condition	A workout record graph with the default filter is displayed in the welcome page.	
Failed End Condition	The welcome page doesn't display the record.	
Primary Actors	Workout User	
Secondary Actors	None	
Trigger	A Workout User visits dashboard page.	
Main Flow	Step	Action
	1	The Workout User visits the “dashboard” page.
	2	The system displays the workout graph with this week's daily workout records.
Extensions	Step	Branching Action

	2.1	There isn't any workout record queried from the database.
	2.2	The system notifies the user no data is available.

3.2.3.4 View shared record

Use case name	View shared record	
Related Requirements	FR-13, FR-14, FR-15, FR-16	
Goal In Context	Invited User views the shared record in the record page.	
Preconditions	A link for the shared record was generated. The shared record's visibility has been changed to "public".	
Successful End Condition	The shared record is displayed in the record page.	
Failed End Condition	The web page doesn't display the shared record.	
Primary Actors	Invited User	
Secondary Actors	None	
Trigger	An Invited User visits the record page with URI for the shared record.	
Main Flow	Step	Action
	1	An Invited User visits the record page.
	2	The system displayed the workout record with appropriate type and filter saved in advance.
Extensions	Step	Branching Action
	2.1-a	There isn't any workout record queried from the database.
	2.2-a	The system notifies the user no data is available.
	2.1-b	The visibility of the workout record is not "public".
	2.2-b	The system notifies the user permission denied.

3.2.3.5 Associated Functional Requirements

FR-13: Display Table

The “table” option shall display a table of which the horizontal axis represents the time and the vertical axis represents the indicator. Both axes' values are specified by the filter. The vertical axis has at least one indicator.

Input: User id, record filters including date range and workout indicators.

Process:

1. The system shall retrieve raw records with given inputs from the Workout Record DB. If no record is available, notify it to the user and terminate.
2. The system shall fill in two axes with specified date range and specified indicators.
3. The system shall fill in numerical values retrieved in 1.
4. The system shall display the constructed table.

Output: Workout record table is displayed.

FR-14: Display Graph

The “graph” option shall display a line graph with the same data with the “table” option. The “graph” option shall display the exact value when the input device hovers on the graph mark.

Input: User id, record filters including date range and a workout indicator.

Process:

1. The system shall retrieve raw records with given inputs from the Workout Record DB. If no record is available, notify it to the user and terminate.
2. The system shall fill in two axes with specified date range and specified indicator.
3. The system shall draw marks and lines between them with numerical values retrieved in 1.
4. The system shall display the constructed line graph.

Output: Workout record graph is displayed.

FR-15: Display Pace

The “pace” option shall display rows of sets conducted during one specific workout. Each row includes time bar with vertical lines marked on it. A vertical line corresponds to a lift. A lift with the satisfied pace is marked green, and red otherwise. All time bars shall follow the common time density. There may be a box indicating rest between two sets.

Input: User id, workout id.

Process:

1. The system shall retrieve raw records with given inputs from the Workout Record DB. If no record is available, notify it to the user and terminate.
2. The system shall draw boxes for workout sets and rest times.
3. The system shall draw time bar and vertical lines with numerical values retrieved in 1.
4. The system shall display the constructed pace log.

Output: Workout pace log is displayed.

FR-16: Retrieve Workout Record

Input: User id of target record, record filters or ranges.

Process:

1. The system shall check if the logged in user has the access to the requesting records is permitted. If not, notify it to the user and terminate.
2. The system shall query the Workout Record DB with conditions and clauses.
3. The system shall notify the user if an error has been occurred in the Workout Record DB and terminate.
4. The system shall return the record.

Output: Requested workout record in a raw format.

FR-17: Share a Record to Social Media

Input: User id, record type, record filters, social media configuration.

Process:

1. The system shall change the visibility of the record to “public”.
2. The system shall generate a URI connected to the visualized record.
3. The system shall make a request of sharing the generated URI to the platform.
4. The system shall notify the user whether the URI to the record was shared.

Output: Shared success message is displayed.

3.2.4 Workout Record Analysis & Prescription

Workout Record Analysis and Prescription System provides analysis based on the user's objective. The Workout User shall select objectives between ‘gain muscle’, ‘lose weight’, and ‘maintain health’. For each objective, there exists different goals that require the user to enter. The system will collect users' Workout Record form Workout Record DB, and save analysis results at Workout User DB. When the user visits Record Analysis page, system loads most recent analysis results from the Workout User DB.

3.2.4.1 Select Objective

Use case name	Select Objective
Related Requirements	FR-18, PNFR-1
Goal In Context	The Workout User select their objective, which affects analysis results and additional information to be entered
Preconditions	The webpage is shown only to users who have already logged in, so the Workout User DB definitely contains the data of the user.
Successful End Condition	The web page displays the success message ‘Objective Selected’. Update user’s objective on Workout User DB
Failed End Condition	The web page doesn’t show the success message
Primary Actors	Workout User
Secondary Actors	Workout User DB

Trigger	The Workout User Selects the objective at the webpage, and presses the submit button.	
Main Flow	Step	Action
	1	The system display available objectives
	2	The Workout User selects the objective
	3	The Workout User press the submit button
	4	The DBMS updates the objective of Workout User
	5	The webpage displays the success message
	6	The webpage displays text input form of 'Enter Goal'

3.2.4.2 Enter Goal

Use case name	Enter Goal	
Related Requirements	FR-19, PNFR-1	
Goal In Context	The Workout User enter their goals, based on their objective.	
Preconditions	The Workout User has selected their goal The input form is provided by system, which is compatible to DB (doesn't occur errors)	
Successful End Condition	The web page displays the success message 'Goal Updated'. Update user's goal on Workout User DB	
Failed End Condition	The web page doesn't show the success message	
Primary Actors	Workout User	
Secondary Actors	Workout User DB	
Trigger	The Workout User enters goal at the Analysis Results page.	
Main Flow	Step	Action
	1	The system displays goal input form
	2	The Workout User enters the goal.
	3	The Workout User press the submit button.
	4	The DBMS updates the goal of Workout User
	5	The webpage displays the success message

3.2.4.3 View Analysis Result

Use case name	View Analysis Results	
Related Requirements	FR-21, FR-22, FR-24, SNFR-1, PNFR-1	
Goal In Context	The system shows analysis results on the webpage.	
Preconditions	There are valid analysis results on the Workout User DB.	
Successful End Condition	The analysis results are displayed on the web page.	
Failed End Condition	The analysis results are not displayed on the web page.	
Primary Actors	Workout User	
Secondary Actors	Workout User DB	
Trigger	Workout User visits or refresh 'Workout Results Analysis' page	
Main Flow	Step	Action
	1	User visits or refresh 'Analysis Workout Results' page
	2	System gets analysis results from Workout User DB
	3	System displays 'progress percentage', 'pace feedback', and 'workout routine prescription' on the Analysis Workout Results
Extensions	Step	Branching Action
	3.1	No objective exists in Workout User DB
	3.2	System display error message 'No objective selected' on the webpage
	4.1	No valid workout record founded
	4.2	System display error message 'No workout record founded' on the webpage

3.2.4.4 View Welcome Message

Use case name	View Welcome Message
Related Requirements	FR-23, SNFR-1, PNFR-1
Goal In Context	The system shall display welcome messages based on workout record analysis on the dashboard page.

Preconditions	Welcome Message is constructed and stored in the Workout User DB.	
Successful End Condition	The system display welcome message on the dashboard page	
Failed End Condition	The system doesn't display welcome message on the dashboard page	
Primary Actors	System	
Secondary Actors	Workout User DB, Workout Record DB	
Trigger	A Workout User logs in.	
Main Flow	Step	Action
	1	Workout User logs in
	2	The system displays the message on the dashboard page
Extensions	Step	Branching Action
	2.1	There are no valid welcome message stored in Workout User DB
	2.2	The system displays message "Try our analysis service"

3.2.4.5 Associated Functional Requirements

FR-18 : Update Objective

Input : User Id, Objective chosen by the workout user.

Process :

1. The workout user select objective between 'gain muscle', 'lose weight', and 'maintain health'
2. The workout user presses the submit button
3. The system update Workout User DB with User ID and new objective

Output : The objective of the workout user in Workout User DB is updated

FR-19 : Update Goal

Input : User Id, Goal [target weight, target calorie, target workout time, target muscle mass]

Process :

1. A workout user enters the goal
2. The workout user presses the submit button
3. The system update Workout User DB with User ID and new goal

Output : The goal of the workout user in Workout User DB is updated

FR-20 : Change Start Date

Input : User Id, Date to be start date

Process :

1. A workout user enters the date
2. The workout user presses the submit button
3. The system update Workout User DB with User ID and new start date

Output : The start date of the workout user in Workout User DB is updated

FR-21 : Check Latest Result

Input : Current date, User Id

Process :

1. The system shall get current date
2. The system shall query Workout Record DB for latest workout record of the User Id
3. The system shall query Workout User DB for latest analysis result of the User Id
4. The system shall compare the timestamp of latest workout record and the latest analysis result
5. Return if the timestamp is equal

Output : True/False

FR-22 : Analyze Workout Record

Input : User Id

Process :

1. The system shall query Workout User DB for start date, objective, target pace, and goals
2. The system shall query Workout Record DB with start date and User Id
3. The system shall calculate progress percent based on goals and workout record
4. The system shall select welcome message based on progress percentage
5. The system shall calculate pace feedback with target pace and workout record
6. The system shall select workout routine prescription from the predefined sets, based on workout record
7. The system shall update analysis results on the Workout User DB

Output : The analyze result is stored on the Workout User DB

FR-23 : Display Welcome Message

Input : User Id

Process :

1. A workout user visits/refreshes dashboard page
2. The system shall query Workout Record DB for welcome message
3. If there are no welcome message on the Workout Record DB, display "Try our analysis service" on the dashboard page
4. If welcome message exists, display it on the dashboard page

Output : Message is displayed on the dashboard page

FR-24 : Display Analysis Result

Input : User Id, Output of FR-18(Check Latest Result)

Process :

1. A workout user visits/refreshes analysis page.
2. The system shall query Workout Record DB for analysis results

3. If there are no analysis results, display message "No results"
 4. If query success, display analysis results on the analysis page.
- Output : Analysis result is displayed on the analysis page

3.3 Performance requirements

This section describes both the static and the dynamic numerical requirements placed on the use of Smart Barbell software. We organized them on a table.

Code	Requirement Description
PR-1	The connection to the Barbell Device shall take less than 30 seconds when a Workout User already knows that they should scan the QR code for connection.
PR-2	Whether the username is already taken or not, verification should take less than 10 seconds.
PR-3	Matching Login information and the one in Work Out DB should take less than 10 seconds.
PR-4	Record Analysis page should be loaded less than 5 seconds when arrived.
PR-5	Verifying if the user record and objective exist in DB should take less than 10 seconds.
PR-6	Saving new account information while creating an account should take less than 20 seconds.
PR-7	When a request to the app server fails, it shall try 2 more times before informing the user of the failure.

3.4 Design constraints

There were some design constraints that we had to consider while developing the idea of Smart Barbell system. First is that the Arduino itself is not very computationally powerful, that not much calculations can be done inside it. Second is that the whole Arduino and sensor system should be small in size. In order for our device to successfully collect data of user exercising, it should be attached to the barbell itself, and the size should be restricted so that it does not affect user exercising.

3.5 Software system attributes

The requirements in this section specify the non-functional requirements classified according to reliability, availability, security and maintainability of Smart Barbell.

3.5.1 Reliability

Code	Requirement Description
RNFR-1	Searched results for Workout User account in the Workout User DB during the Login procedure should be always right. When 100 searches are done, all 100 searches should return right user information.
RNFR-2	Detection of a lift shall always be accurate. When 50 lifts are done, 48 or more lifts shall be detected with the data saved on the Workout Record DB.
RNFR-3	The recognition of the top point and the bottom point of the barbell shall not be delayed by 0.2 seconds. When testing the lift recognition with a beeper, after reaching the top point, the beeper shall beep before coming back to the bottom point.

3.5.2 Availability

Code	Requirement Description
ANFR-1	More than two users shall be able to simultaneously connect to Smart Barbell.
ANFR-2	Smart Barbell device should be connected to Internet.

3.5.3 Security

Code	Requirement Description
SNFR-1	Workout Data that is older than 1 year should be deleted from the DB.
SNFR-2	Only administrators should have access to other work out user accounts.

3.5.4 Maintainability

Code	Requirement Description
MNFR-1	Whole system should be managed under Git, to keep track of file versions and commit records.
MNFR-2	Test cases and testing environment should be prepared.

3.5.5 Portability

Code	Requirement Description
PNFR-1	Web Interface should be accessible to all mobile phones, or tablets, despite their different display sizes.