

T-Mobile Carelink+ X Heal – Assistant for ACL Recovery

Github: https://github.com/LydiaZZzz/X_Heal.git

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- 04** Budget Update
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01

Problem Statement

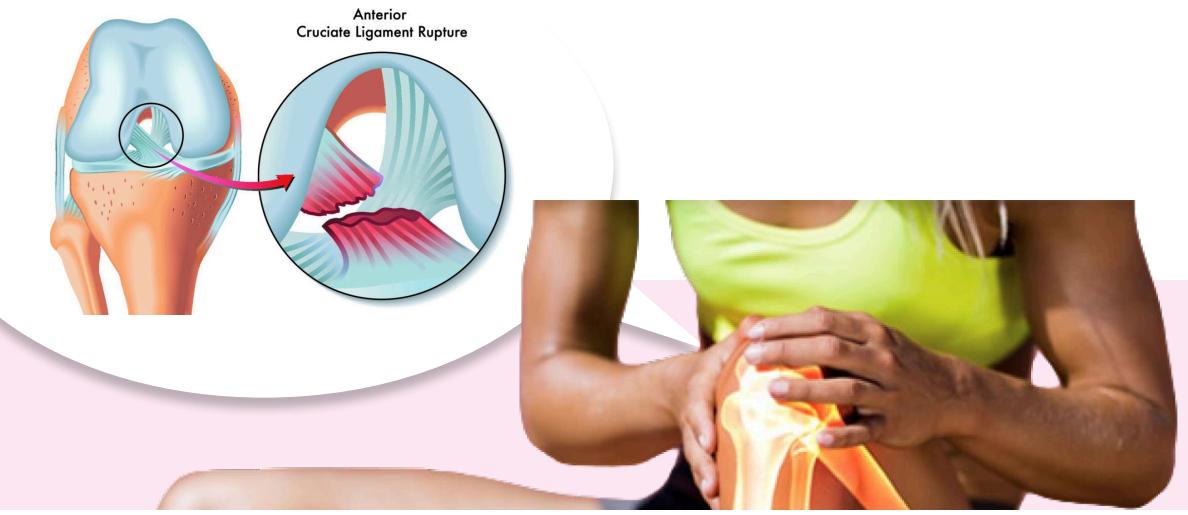
Background

Anterior Cruciate Ligament (ACL)

An ACL injury is a tear or sprain of the anterior cruciate ligament.

ACL Injury Frequency:

1 in 3500 People Annually



Much of the success of ACL surgery depends on the patient's dedication to rigorous physical therapy.

Current Rehab Pain Points



Must rely on face-to-face to assess progress

Without real-time home data, therapists must use in-person assessments to decide rehabilitation advancement.



Hard to perform exercises correctly at home

Patients struggle with exercise accuracy due to unclear guidance and fear of doing wrong.

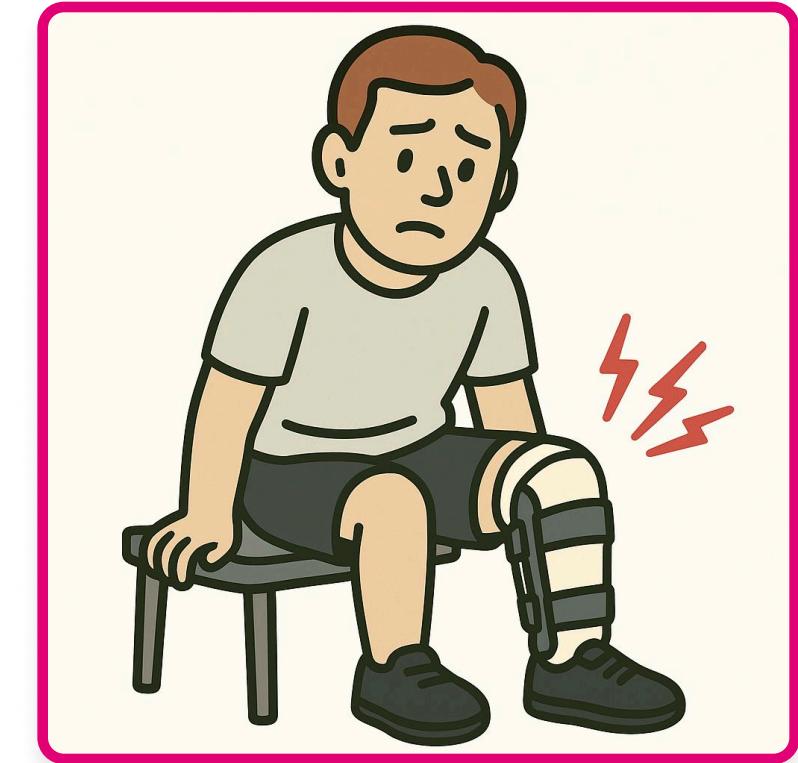


Difficult to stay motivated over a long rehab

The year-long rehabilitation process makes it hard for patients to maintain daily motivation.

Intended User Group

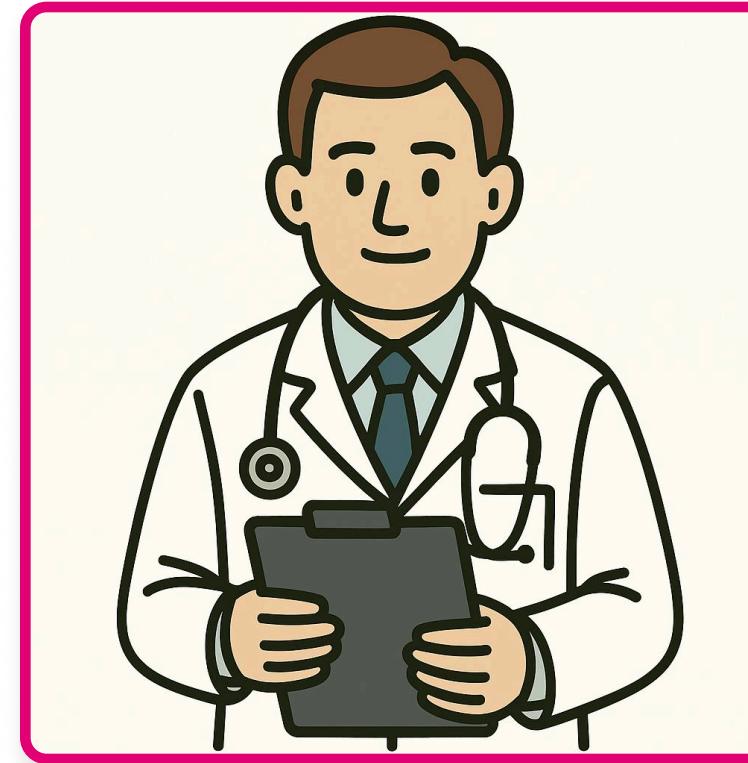
Our system serves **ACL rehab patients** and their **healthcare providers**.



Primary Users: Patients

ACL surgery patients in early to mid rehab

- They need:
- Clear home exercise guidance
 - Motivation to stay consistent
 - Real-time feedback on progress



Secondary Users: Therapists

Professionals who create and adjust rehab plans

- They need:
- Remote monitoring of patient activity
 - Accurate knee/ankle data
 - Auto-generated progress reports

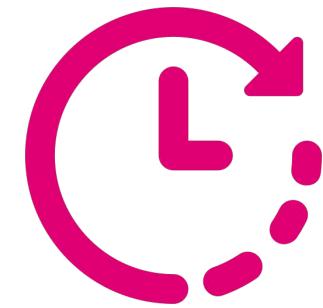
02

Solution Exploration

Solution

X Heal is a wearable system designed to assist ACL patients in performing and tracking rehabilitation exercises with clinical accuracy at home, while enabling therapists to remotely monitor progress and adjust plans based on real-time data.

Desired Feature



User Motivation Enhancement

Leverage a basic reward system and remote supervision features to encourage consistent engagement in home rehabilitation.



Timely Corrective Feedback

Support accurate exercise execution with real-time error detection and response.



Remote Monitoring

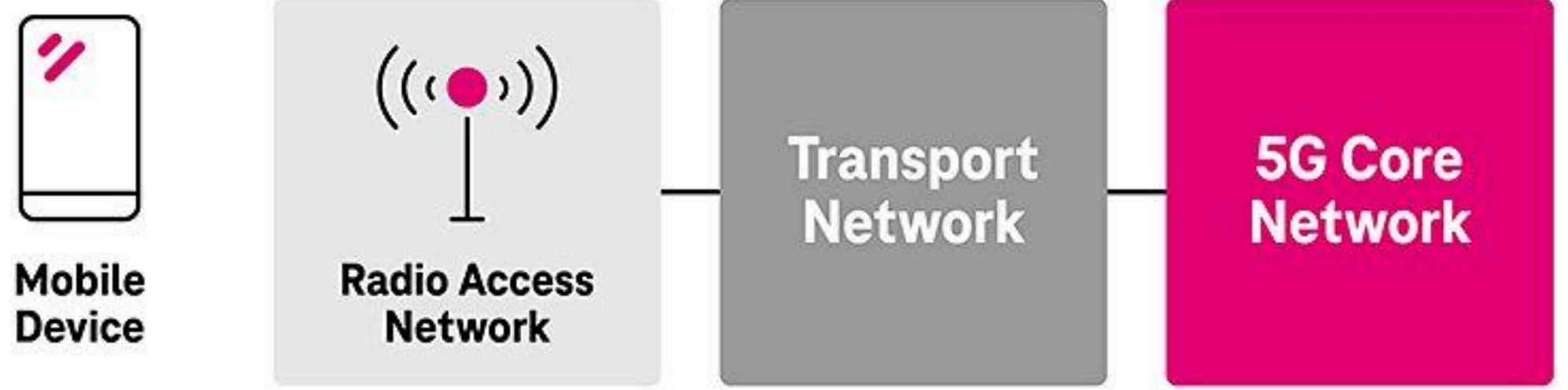
Enable clinicians to oversee patient progress and adjust rehabilitation plans remotely.



Secure Data Transmission

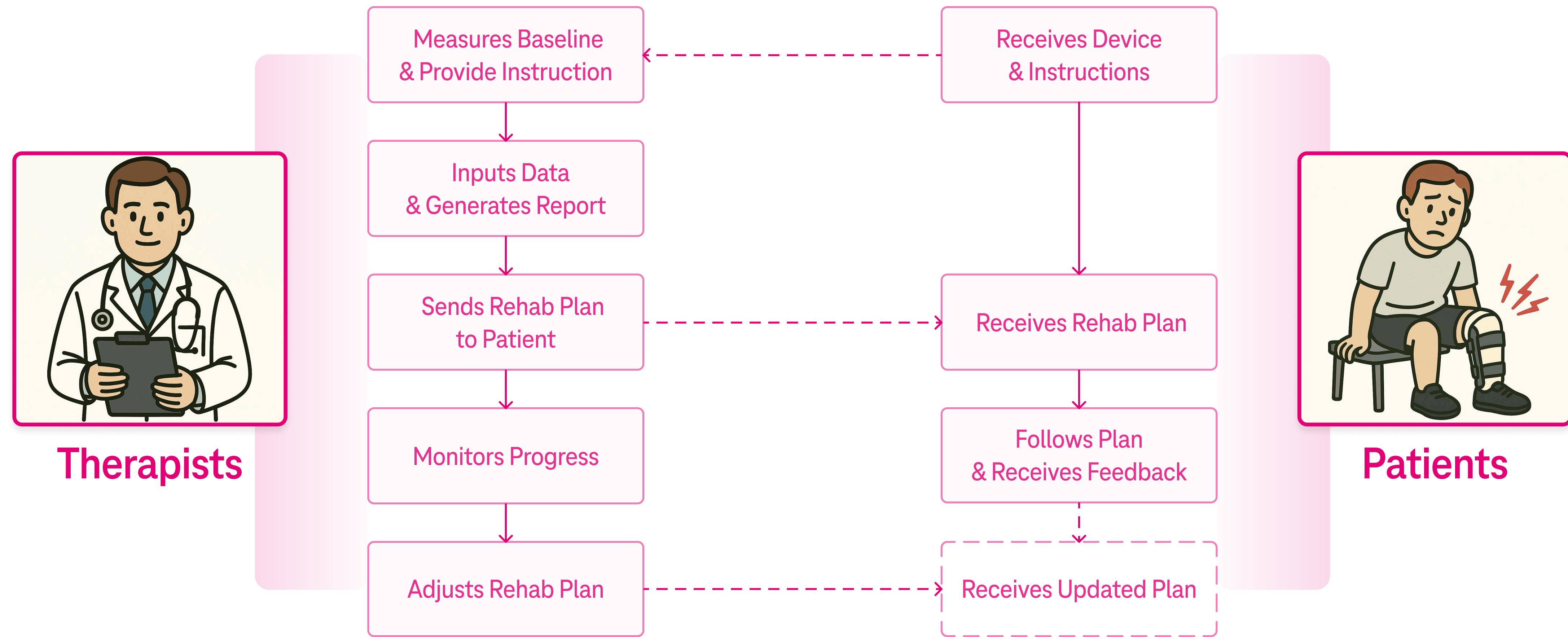
Investigate high-speed, privacy-focused transmission methods, including 5G connectivity.

5G Integration Proposal



- Supports encrypted, privacy-focused data sharing
- Real-time transmission of rehab movement data to the cloud
- Enhanced stability and speed in remote environments
- Expands access to guided rehab beyond clinical settings

User Flow Diagram



Movement Standard



Hip flexion (lying down, leg straight)



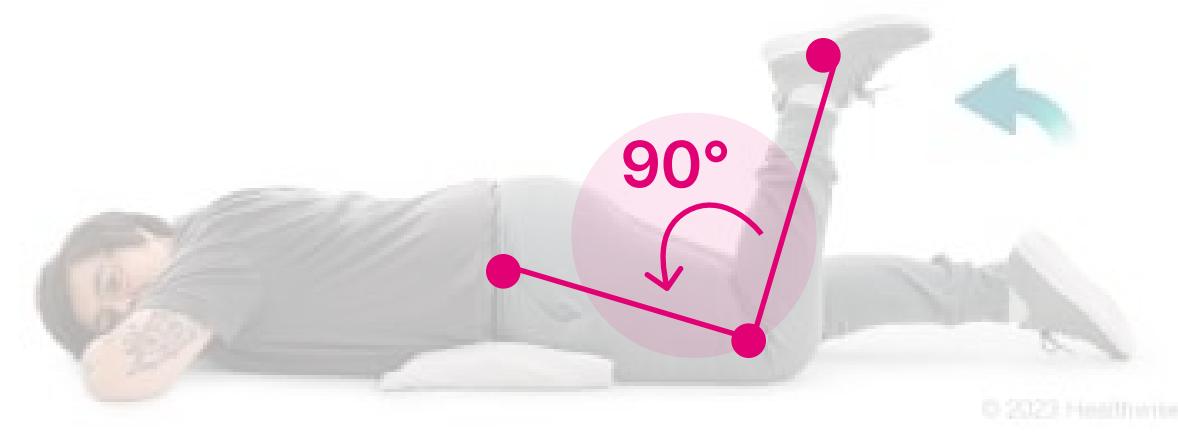
Hamstring curl (lying down)



Heel raise



Hold for about 6 seconds
Repeat 8 to 12 times



Repeat 8 to 12 times

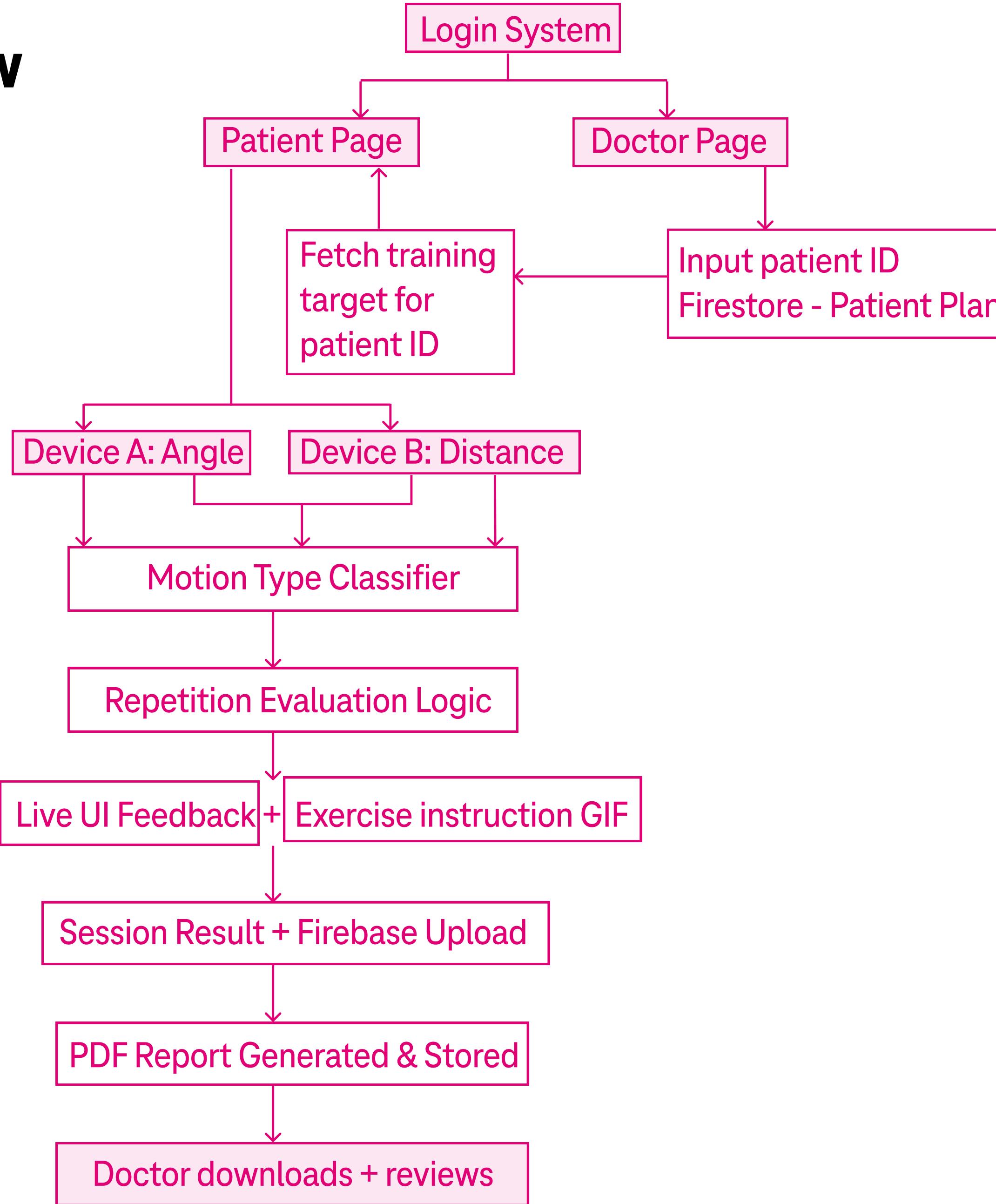


Hold for about 6 seconds
Repeat 8 to 12 times

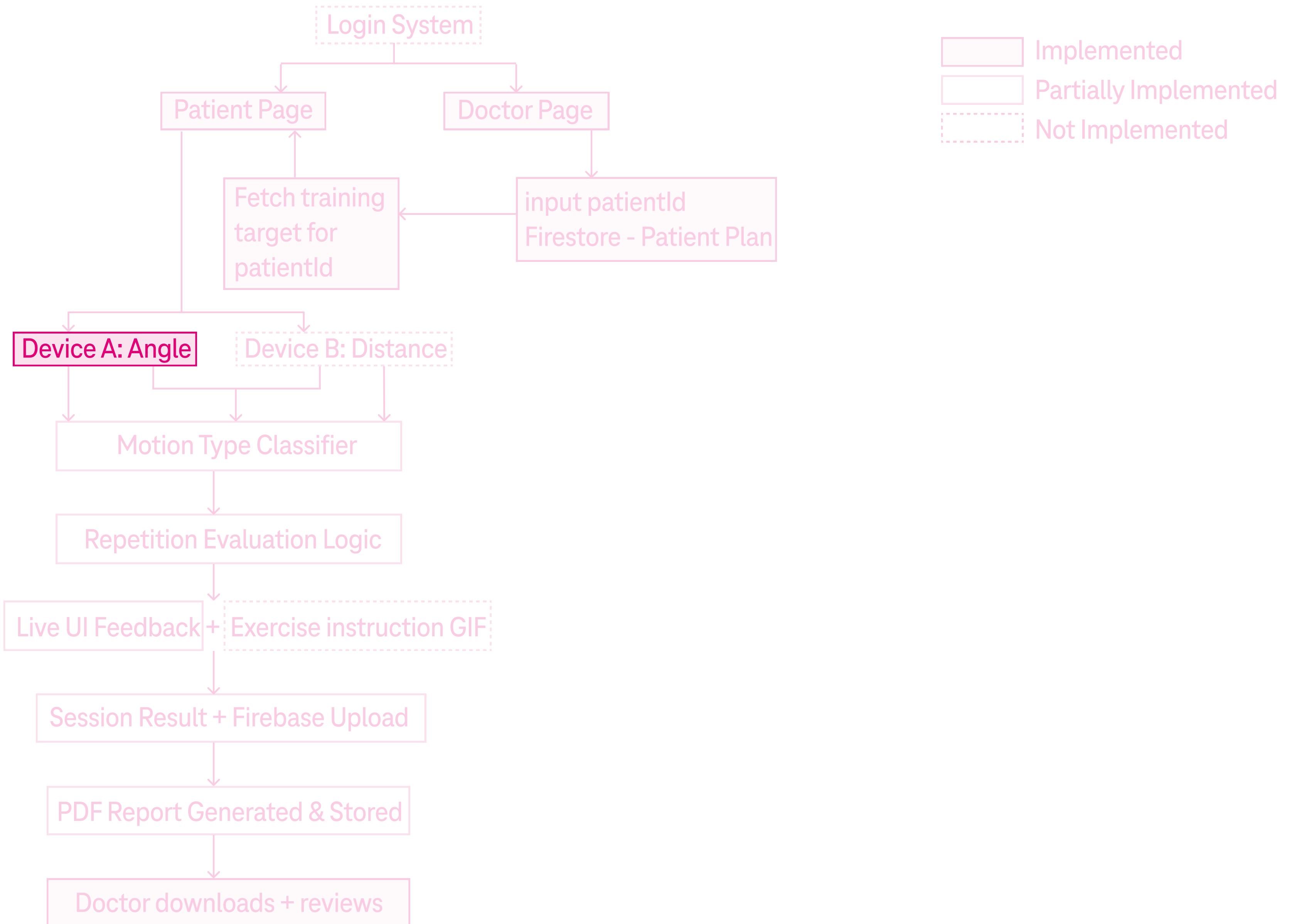
03

Data Pipeline

Data Pipeline Overview

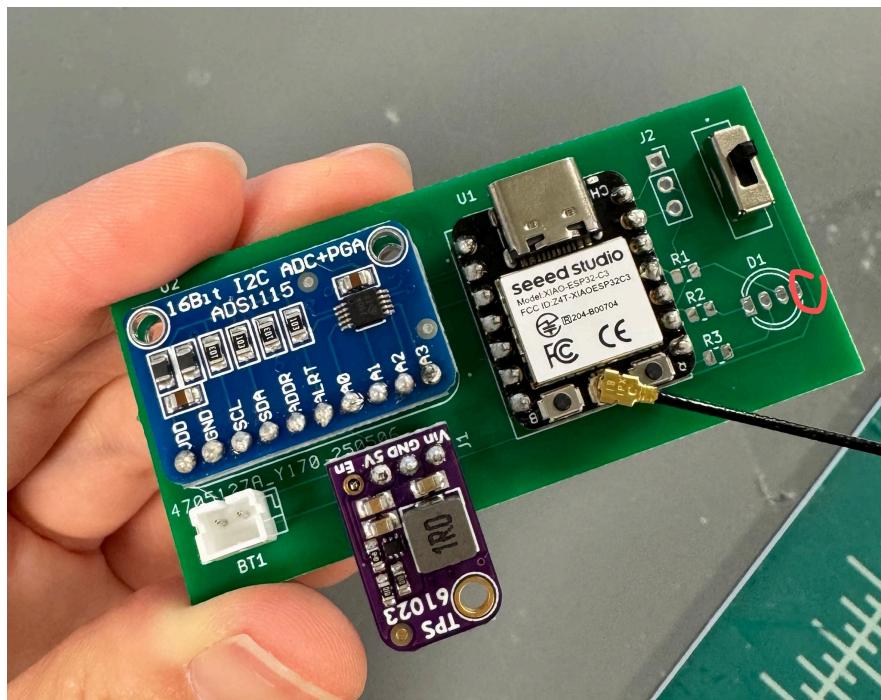


Device A - Angle



Device A - Angle - Circuit

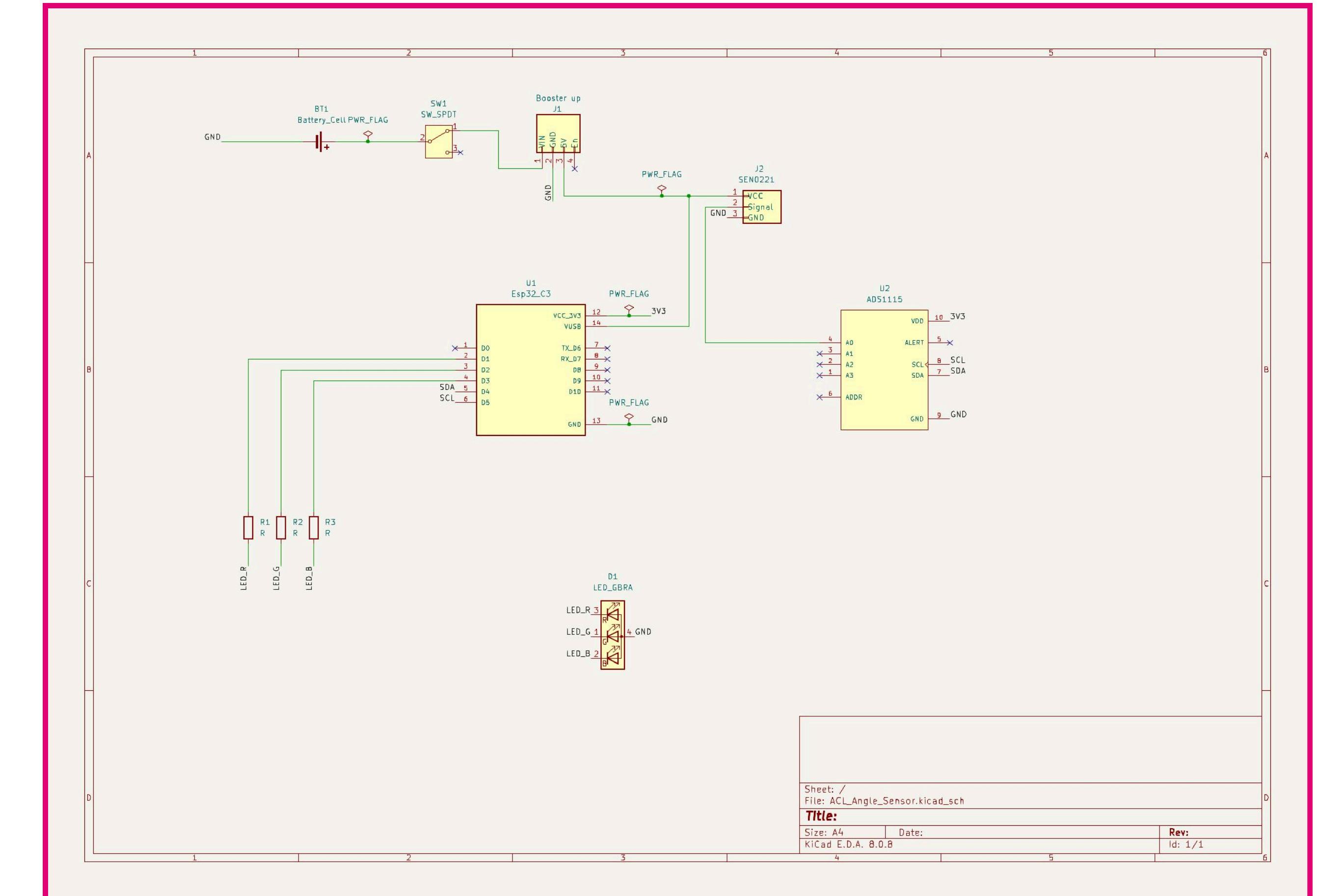
SEN0221



TPS61023



ADS1115



Device A - Angle -Assembling

Parts Diagram



Assembly Process



Assembled Product

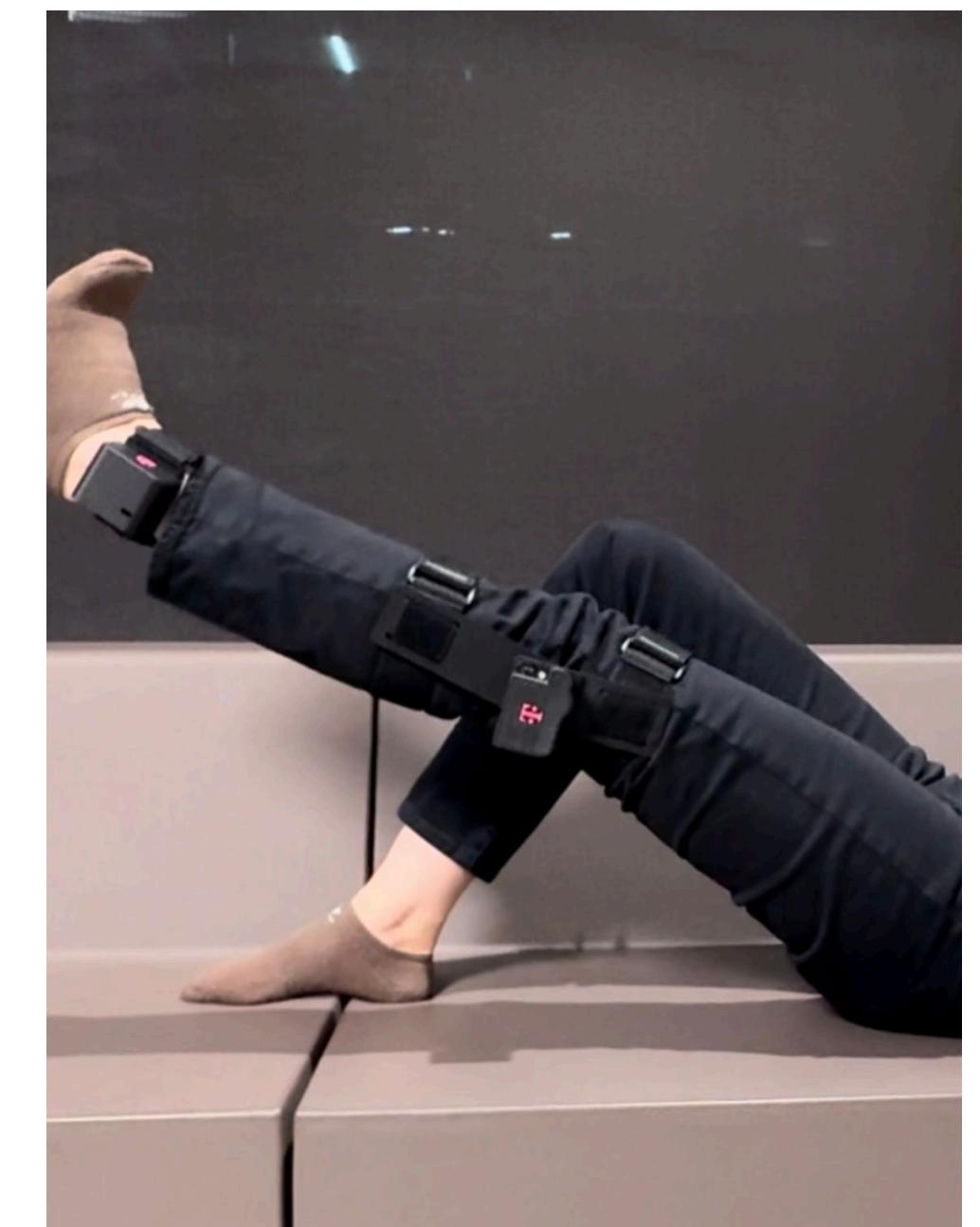


Device A - Angle -Iteration

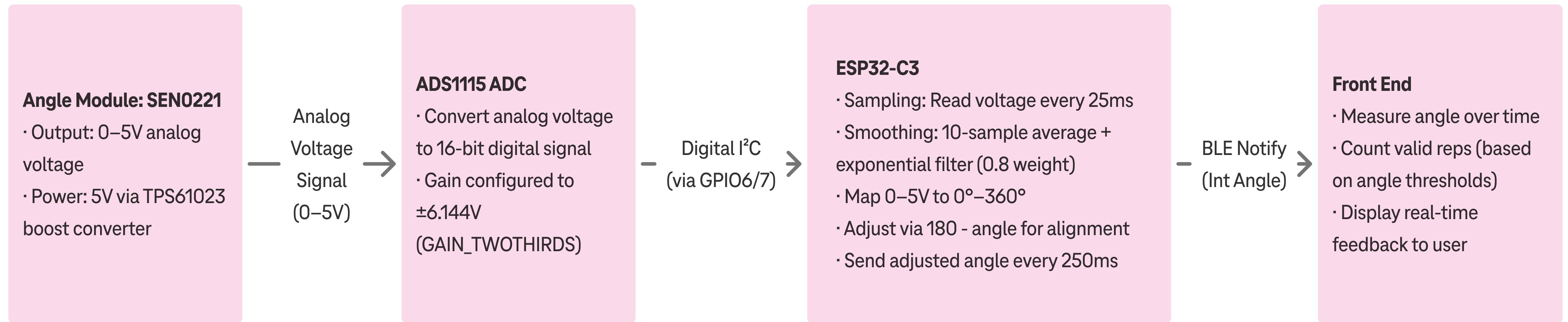
Previous Version



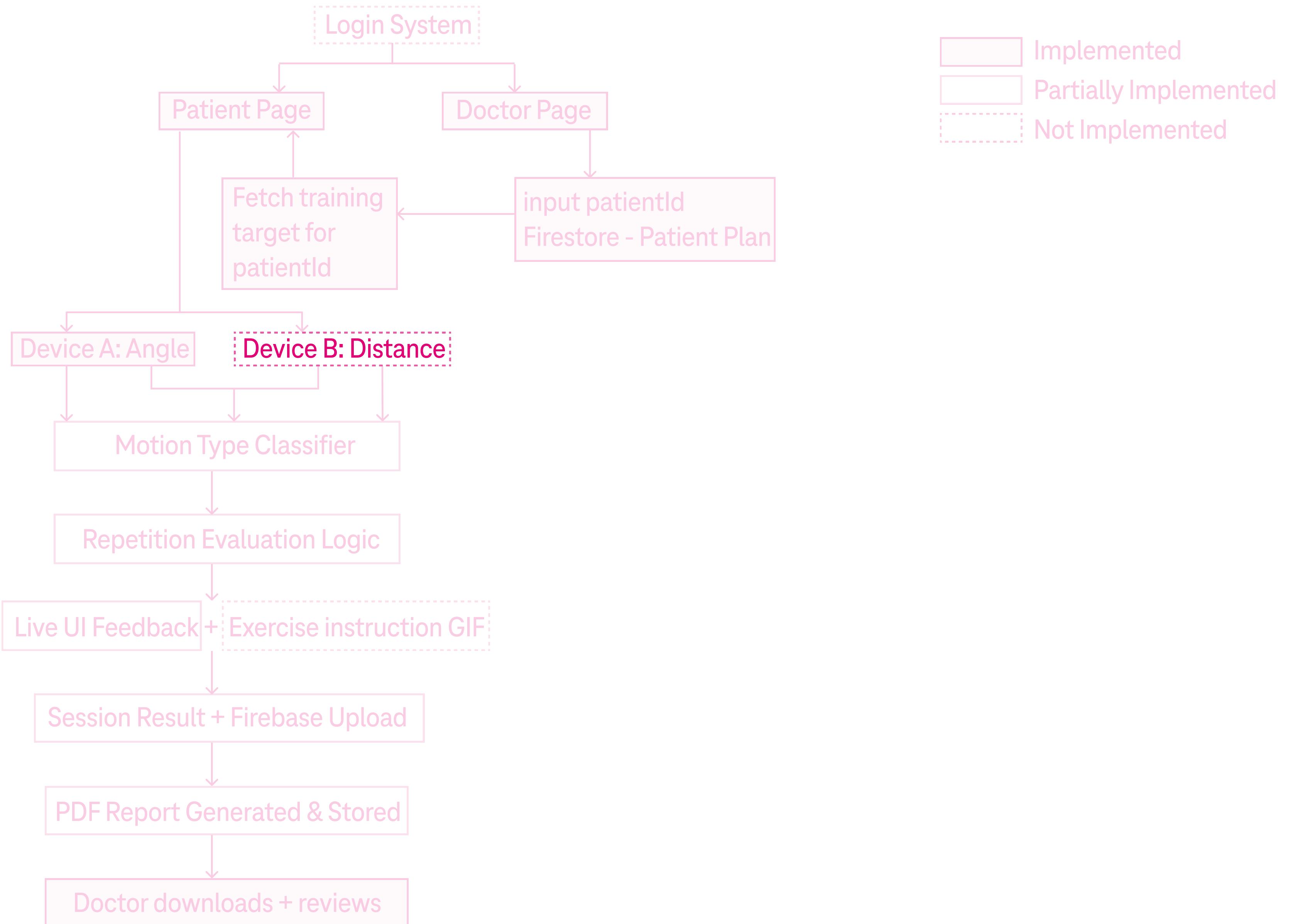
Current Version



Device A - Angle - Data Pipeline



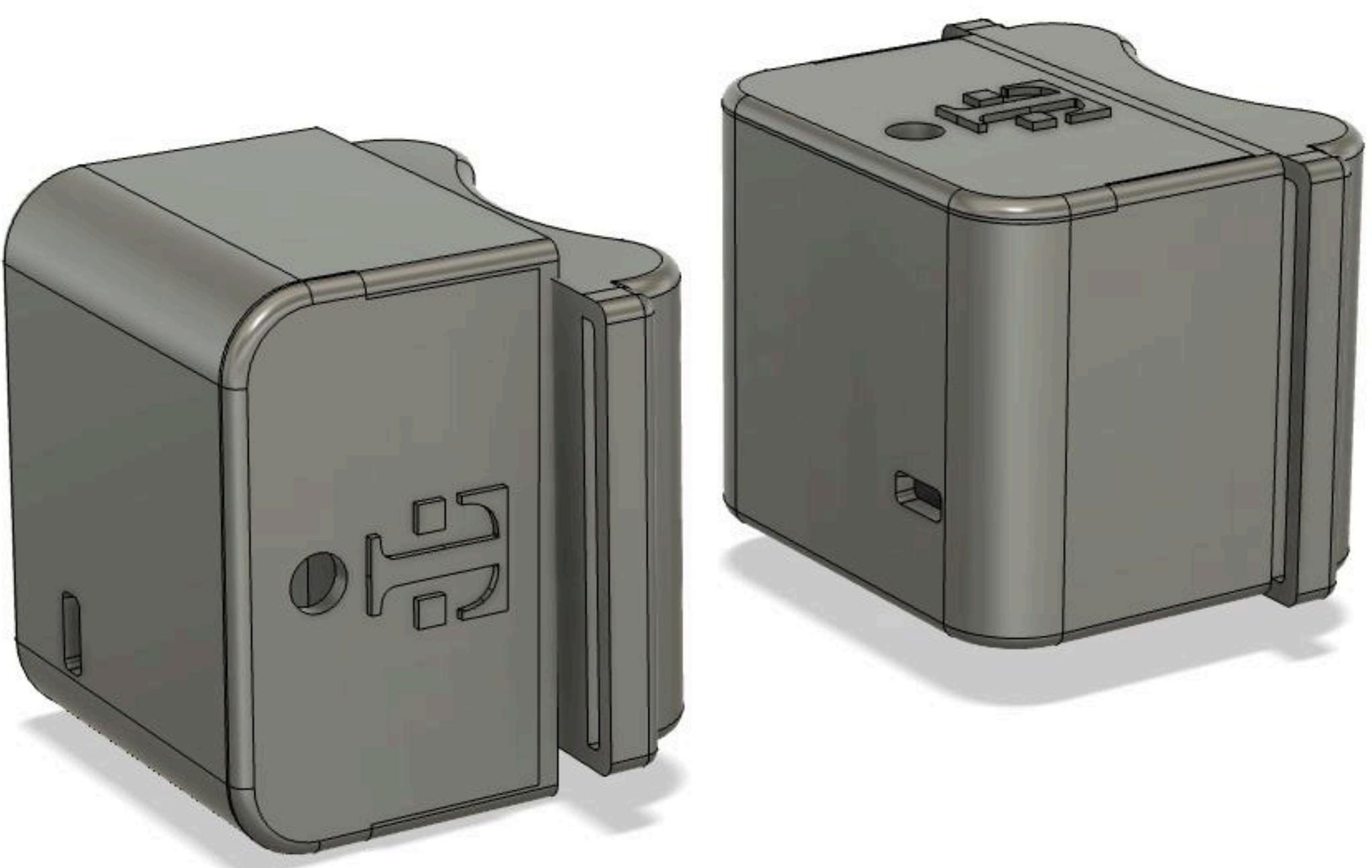
Device B - Distance



Device B - Distance

Adaptive Orientation Design

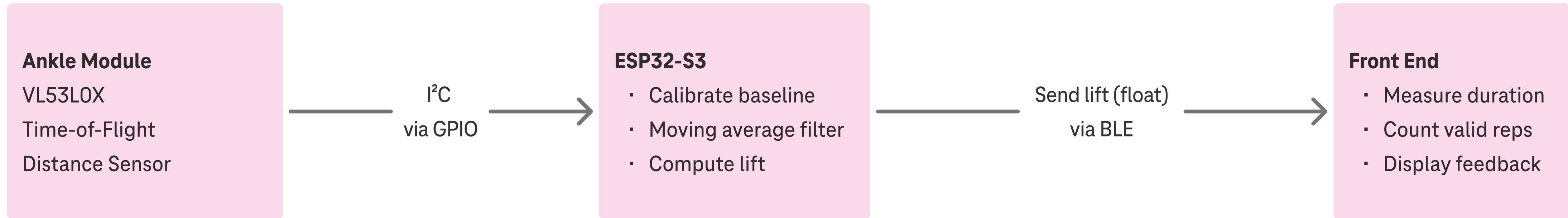
To support both standing and supine heel raise exercises, the enclosure allows the sensor module to rotate 90°, ensuring it consistently faces the ground for accurate measurement.



Iterations



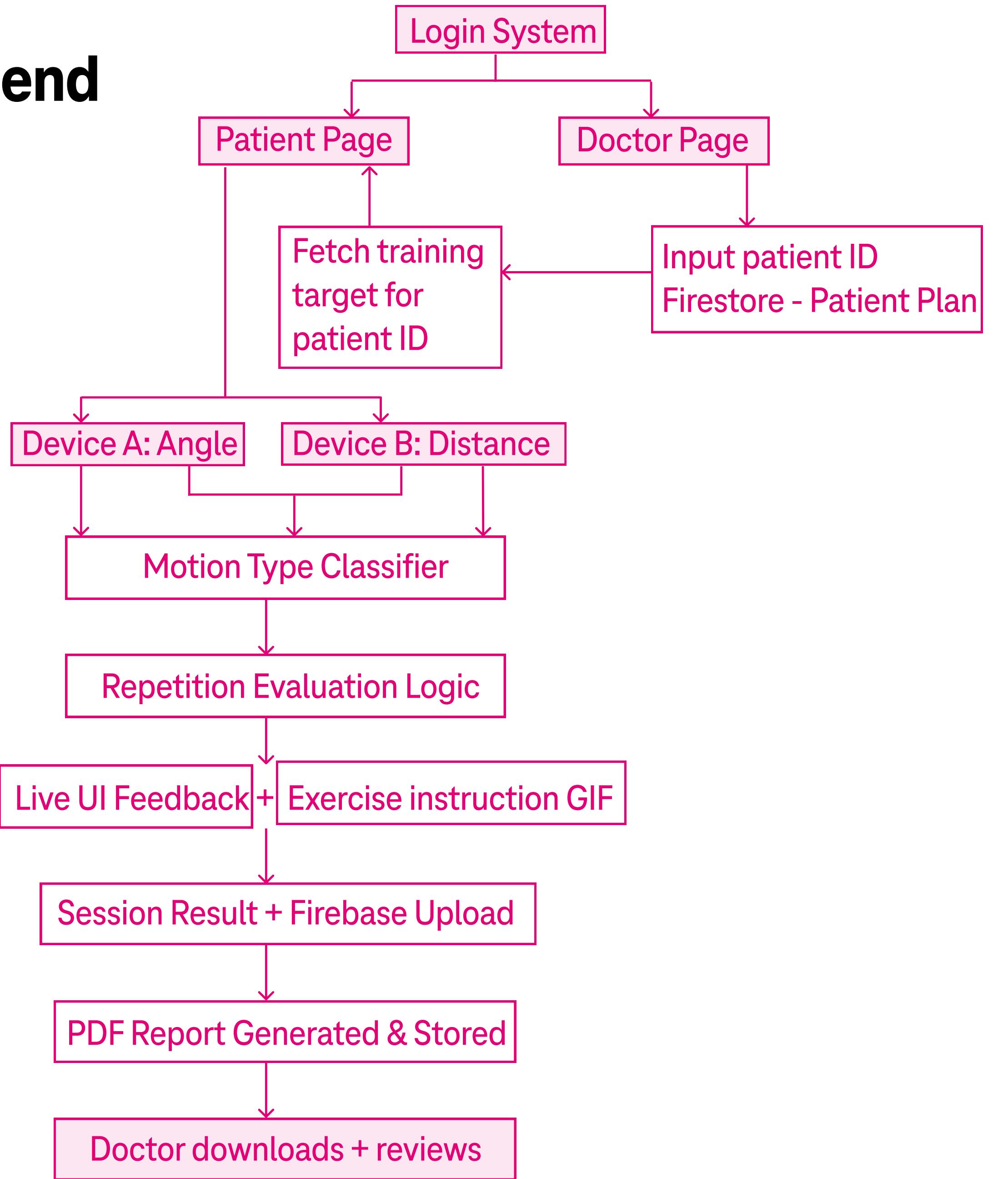
Device B - Distance - Data Pipeline



```
23:17:34.617 -> 92185,5  
23:17:34.848 -> 92426,18  
23:17:35.078 -> 92667,30  
23:17:35.309 -> 92908,41  
23:17:36.229 -> ✓ VL53L0X Initialized.  
23:17:40.481 -> 🔎 Calibrated baseline: 37 mm  
23:17:40.744 -> ⚙️ BLE advertising started, waiting for device B...  
23:17:40.777 -> 5093,-32  
23:17:41.009 -> 5334,-26  
23:17:41.272 -> 5575,-19  
23:17:41.502 -> 5815,-13  
23:17:41.733 -> 6056,-6
```

Baseline Calibration

Front-end



Rehabilitation Training

Motion Type: Hamstring Curl

Repetition	Status	Time
0	idle	0.0

Angle: --°

Motion Type: Hamstring Curl

Feedback: Current motion: Hamstring Curl

Current/Target: --/70

GIF

Refresh

Connect Device A (Angle Sensor)

Status: Not connected

Angle: --

Upload Daily Report

Export & Upload PDF

F Mobile

Rehab Parameters Reports Analytics Settings Help

Good to see you, Dr. Smith!

Today's Priorities

3 patients require immediate follow-up.

VIEW PATIENT LIST

Patient Report Overview

Patient Information

John Doe | ID: 1234 | Phase Early

Latest Exercise Report

Latest Report: May 13, 2025
Generated from John's most recent session

VIEW PDF REPORT

T Mobile

Home Rehab Parameters Reports Analytics Settings Help

Patient Rehab Parameters

Patient Information

Patient ID: [Input] Patient Name: [Input]

Rehabilitation Phase: Early

Measurements

Leg Length (cm): 0

Exercise Parameters

Hip Flexion: Target Angle (°): 30 | Hold Time (s): 5 | Repetitions: 10

Knee Flexion: Target Angle (°): 90 | Hold Time (s): 5 | Repetitions: 10

Heel Raise: Target Height (cm): 0 | Hold Time (s): 5 | Repetitions: 10

Training Frequency

Sessions per Day: 2

Session & Follow-up Time

Session Start Time: mm/dd/yyyy, --:-- Follow-up Time: mm/dd/yyyy, --:--

UPLOAD DATA

Project Overview

Firestore Database

Storage

Product Categories

Build

run

analyze

AI

All Products

Related development tools

Firebase Studio

Checks

Blaze

Pay as you go

Revise

(default) patient_exercise_reps demo_patient_2025-05-12T02:47:40.782Z

+ 开始收集 patient_daily demo_patient_2025-05-12T02:47:40.782Z

+ 添加文档 patient_exercise_reps > demo_patient_2025-05-12T02:47:40.782Z

+ 开始收集 patients demo_patient_2025-05-12T02:47:40.782Z

+ 添加字段 patients > demo_patient_2025-05-12T02:47:40.782Z

patients > demo_patient_2025-05-12T02:47:40.782Z

reports > demo_patient_2025-05-12T02:47:40.782Z

demo_patient_2025-05-12T02:47:40.782Z

: demo_patient_2025-05-12T02:47:40.782Z

index: 2

minValue: 66

values

0 173

1 129

2 84

3 69

4 67

5 66

6 66

7 66

Google Cloud 中的更多功能

项目概览

Firestore Database

Storage

产品类别

构建

运行

分析

AI

All Products

Related development tools

Firebase Studio

Checks

Blaze

Pay as you go

Revise

x-heal.firebaseioapp.com

需要我们帮助您上手使用 Storage? 向 Gemini 提问

文件 规则 使用量 Extensions

① 查看与 Cloud Storage for Firebase 定价方案要求有关的变更 了解详情 关闭

gs://x-heal.firebaseiostorage.app > doctor > reports

名称 大小 类型 上次修改时间

exercise_repo_rt_17470417 3.98 KB application/pdf 2025年5月12日 25602.pdf

exercise_repo_rt_17470418 5.87 KB application/pdf 2025年5月12日 55073.pdf

上传文件

gs://x-heal.firebaseiostorage.app > X-Heal-Reports > 1223 > Mid

name size type Last modified time

2025-05-11_19-47-42-report.pdf 5.3 KB application/pdf 2025年5月11日

2025-05-11_19-47-43-report.pdf 5.3 KB application/pdf 2025年5月11日

Upload files

Storage x-heal.firebaseiostorage.app Need help getting started with Storage? Ask Gemini a question

document rule Usage Extensions

Protect your Storage resources from misuse, such as billing fraud or phishing attacks Configuring App Check

Review changes to Cloud Storage for Firebase pricing plan requirements Learn more

gs://x-heal.firebaseiostorage.app > X-Heal-Reports > 1223 > Mid

name size type Last modified time

2025-05-11_19-47-42-report.pdf 5.3 KB application/pdf 2025年5月11日

2025-05-11_19-47-43-report.pdf 5.3 KB application/pdf 2025年5月11日

Upload files

Firebase

Project Overview

Storage

Firebase Database

Product Categories

Build

run

analyze

AI

All Products

Related development tools

Firebase Studio

Checks

Blaze

Pay as you go

Revise

gs://x-heal.firebaseiostorage.app > patients > 1223 > reports > 2025-05-12T02:47:40.782Z

+ Start collecting reports > 2025-05-12T02:47:40.782Z > 2025-05-12T02:47:43.250Z

+ Add fields exists: true lastUpdated: "2025-05-12T02:47:43.250Z"

+ latestReport

exists: true lastUpdated: "2025-05-12T02:47:43.250Z"

pdfUrl: "https://firebasestorage.googleapis.com/storage/v1/b/x-heal.firebaseiostorage/o/reports%2F1223%2FMid%2F2025-05-11_19-47-43-report.pdf?alt=media&token=3c3c4405b2584522-bd65-f8e95476103e"

parameters

heelRaise holdTime: 5 frequency: 2

holdTime: 5 repetitions: 10

targetHeight: 7

hipFlexion holdTime: 5 timestamp: 1683811030

Database location: name

Firebase

Project Overview

Storage

Firebase Database

Product Categories

Build

run

analyze

AI

All Products

Related development tools

Firebase Studio

Checks

Blaze

Pay as you go

Revise

gs://x-heal.firebaseiostorage.app > patients > 1223 > reports > 2025-05-12T02:47:40.782Z

+ Start collecting reports > 2025-05-12T02:47:40.782Z > 2025-05-12T02:47:43.250Z

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+ latestReport

exists: true lastUpdated: "2025-05-12T02:47:43.250Z"

pdfUrl: "https://firebasestorage.googleapis.com/storage/v1/b/x-heal.firebaseiostorage/o/reports%2F1223%2FMid%2F2025-05-11_19-47-43-report.pdf?alt=media&tken=3c3c4405b2584522-bd65-f8e95476103e"

parameters

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holdTime: 5 repetitions: 10

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Database location: name

Firebase

Project Overview

Storage

Firebase Database

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Build

run

analyze

AI

All Products

Related development tools

Firebase Studio

Checks

Blaze

Pay as you go

Revise

gs://x-heal.firebaseiostorage.app > patients > 1223 > reports

+ Start collecting reports > 2025-05-12T02:47:40.782Z > 2025-05-12T02:47:43.250Z

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pdfUrl: "https://firebasestorage.googleapis.com/storage/v1/b/x-heal.firebaseiostorage/o/reports%2F1223%2FMid%2F2025-05-11_19-47-43-report.pdf?alt=media&tken=3c3c4405b2584522-bd65-f8e95476103e"

parameters

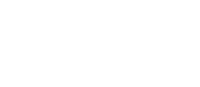
heelRaise holdTime: 5 frequency: 2

holdTime: 5 repetitions: 10

targetHeight: 7

Database location: name

Doctor Page



Overview Dashboard

Doctors can check upcoming appointment, prioritized patients, and core statistics of patients.

The screenshot shows a tablet displaying the Doctor Page dashboard. The top navigation bar includes the T-Mobile logo, a search bar, and a user profile for Dr. Smith (Orthopedic surgeon). Below the navigation is a sidebar with the X-Heal logo and links for Overview, Patients, and Appointment. A "Need Help?" button is also present. The main content area features several cards: "Upcoming Appointment" showing an appointment for Olivia Brown at 10:30 AM with options to "View Plan" or "Start Session"; "Follow-up Needed" showing 6 patients; "Today's Session" showing 5 assessments; "Today's Appointment" listing five appointments for John Doe, Jennifer P., Mark Lee, Monica Wang, and Monica Wang; and "Prioritized Patients" listing four entries for John Doe with actions like "Review Progress" and "Send Reminder". A calendar for October 2025 is also visible on the right side.

Welcome, Dr. Smith !

X-Heal

T Mobile

Overview

Patients

Appointment

Upcoming Appointment

View All

10:30 AM In 10 min

Olivia Brown

Priority: High Rehab Phase: Mid

ID: Olivia5678 Note: Monthly checkup

View Plan

Start Session

Follow-up Needed

6 Patients

Today's Session

5 Assessments

Today's Appointment

View All

11:30 AM John Doe Rehab Phase: Mid Note: Monthly checkup Arrived

12:30 AM Jennifer P. Rehab Phase: Mid Note: Monthly checkup Arrived

14:30 AM Mark Lee Rehab Phase: Mid Note: Monthly checkup Arrived

15:30 AM Monica Wang Rehab Phase: Mid Note: Monthly checkup Arrived

15:30 AM Monica Wang Rehab Phase: Mid Note: Monthly checkup Arrived

Prioritized Patients

View All

Name	Action	Last Exercise
John Doe	Review Progress	12 Days
John Doe	Send Reminder	9 Days
John Doe	Send Reminder	8 Days
John Doe	Send Reminder	7 Days

October 2025

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25

Active Patients

12 Patients

Need Help?

Doctor Page

Patient List

Doctors can get a clear overview of patients organized by priority.

The Patients screen displays a list of 10 patients:

Name	ID	Priority	Rehab Phase	Last Exercise	Next Assessment	Actions
John Doe	12345	High	Mid	12 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Jennifer P	12345	High	Mid	8 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Monica Wang	12345	High	Mid	7 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Jennie Kim	12345	High	Mid	6 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Victoria Miller	12345	Mid	Mid	4 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Zach Jackson	12345	Mid	Mid	4 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Dylan Smith	12345	Mid	Mid	3 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Emma J.	12345	Low	Mid	1 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>
Jennifer P	12345	Low	Mid	0 Days	05/26/2025	<button>View Reports</button> <button>Edit Plan</button>

Patient Page

T-Mobile

X-Heal

- Overview
- Rehabing
- Rehab Records
- Profile

ACL Rehab Monitor

Hypertension Monitor

Need Help?

Welcome, Olivia Brown !

👋👋 Welcome to X-Heal – Your ACL Recovery Companion

X-Heal helps you stay on track with your daily rehab exercises after ACL surgery. Follow step-by-step guidance based on your doctor's plan, and automatically share your progress with your care team. Stay consistent. Stay connected. Recover faster.

REHAB COMPLETION OVERVIEW

100 DAYS from Surgery Day: 01/29/2025

25 Days Partially Completed 50 Days Completed

● Completed ● Partially Completed ● Not Completed

CURRENT PHASE EXERCISE TRACKER

Current Phase : Rehab Phase II

Rehab Exercise 1 - Hip Flexion	05/15 05/16 05/17 05/18 05/19 05/20 05/21 05/22 05/23 05/24 05/25 05/26 05/27 05/28 05/29 05/30	18/23
Rehab Exercise 2 - Hamstring Curl	05/15 05/16 05/17 05/18 05/19 05/20 05/21 05/22 05/23 05/24 05/25 05/26 05/27 05/28 05/29 05/30	15/23
Rehab Exercise 3 - Heel Raise	05/15 05/16 05/17 05/18 05/19 05/20 05/21 05/22 05/23 05/24 05/25 05/26 05/27 05/28 05/29 05/30	19/23

■ Completed ■ Not Completed

TODAY'S EXERCISE CHECKLIST

View Latest Instruction

Rehab Exercise 1 - Hip Flexion

180°

30cm

Status: Completed
Estimated Time: ~8 min

Try Again

Rehab Exercise 2 - Hamstring Curl

90°

Status: Incompleted
Estimated Time: ~12 min

Start Exercise

Rehab Exercise 3 - Heel Raise

2.5-5cm

Status: Incompleted
Estimated Time: ~6 min

Start Exercise

Olivia Brown 5678 >

UW Medical Center - Northwest

Patient Page

T-Mobile

X-Heal

- Overview
- Rehabing
- Rehab Records
- Profile

ACL Rehab Monitor

Hypertension Monitor

Need Help?

X-Heal -- Profile

⚠️ Here, you can only view your information. To make any changes, please contact your primary doctor.

PATIENT INFORMATION



Olivia Brown | ID 5678
25 Years Old, Female | Blood: O

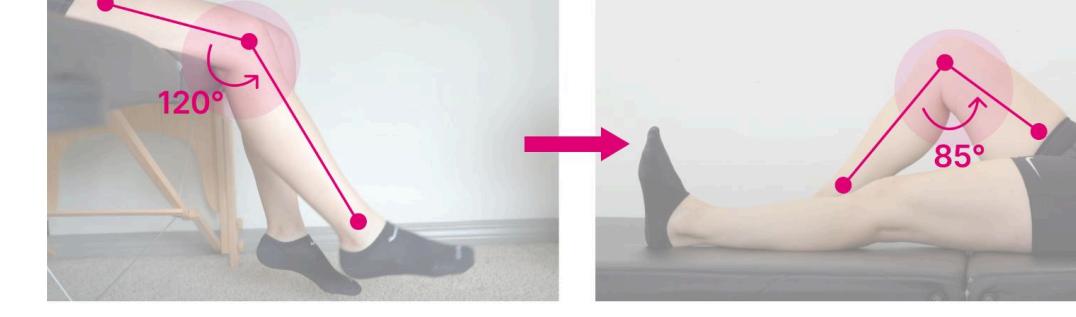
Email	Contact
oliiibrown@outlook.com	+1 (720) 298 7718
Address	12190 NE District Wy, Bellevue, WA 98005
Injured Side	Surgery Date
Right Knee Joint	01/29/2025
Primary Doctor	Medical Facility
Dr Smith - 6578	UW Medical Center - Northwest

SURGERY DAY: 01/29/2025

Phase 1: Completed Phase 2: 04/30/2025 - NOW

FLEXION PROGRESS

Flexion On Surgery Day (01/29/2025) Most Recent Flexion Measurement (04/21/2025)



APPOINTMENT REMINDER

This month: May

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
27	28	29	30	1 9:00 PT	2	3
4	5	6	7 9:00 PT	8	9	10
11	12	13	14 9:00 PT	15	16	17
18	19	20	21 9:00 PT	22	23	24
25	26	27	28 9:00 PT	29	30 15:00 IPC	31
1	2	3	4	5	6	7

Physical Therapy In-Person Consultation

Demo Time

04

Budget Update

Budget Update

Item	Amount	Unit Price	Total Price
Seeeduino ESP32S3	2	\$7.49	\$14.98
VL53L0X Time-of-Flight Distance Sensor	1	\$14.94	\$14.94
Hall Angle Sensor	1	\$27.09	\$27.09
RGB LED	2	\$2.00	\$4.00
3.7V Lipo Battery 1400mAh	1	\$8.65	\$8.65
3.7V Lipo Battery 1200mAh	1	\$8.54	\$8.54
Cinch Strap 6pcs	1	\$16.10	\$16.10
OVERTURE PETG 3D Printer Filament 1.75mm	1	\$22.98	\$22.98
ANYCUBIC PLA+ 3D Printer Filament Bundle	1	\$25.90	\$25.90
			\$143.18

05

Reflection

Hardware Challenges

Angle Device

One of the main challenges we encountered was the voltage incompatibility between the angle sensor and the ESP32-C3. The angle sensor operates with a 5V input and outputs a 5V analog signal, whereas the ESP32-C3 is designed to work with 3.3V logic levels and cannot safely handle 5V inputs.

To solve this, we introduced a TPS voltage regulator to provide a stable 5V power supply for the sensor. Additionally, we integrated an external ADC (Analog-to-Digital Converter) that is compatible with the ESP32-C3's 3.3V input range. This setup allows us to accurately read the sensor's output without damaging the ESP32-C3, ensuring both signal integrity and hardware safety.

Software Challenges

In our project, the majority of the gesture recognition logic and algorithms were implemented on the frontend. We spent a significant amount of time making sure these components worked correctly.

Our development process followed a functionality-first approach. We prioritized backend and feature implementation early on, and only started working on frontend design in the final week. One major challenge we encountered was that the frontend design phase began too late, leaving us with limited time to refine UI details. In the future, we should allocate more time to improving frontend presentation and user experience.

Additionally, integrating our login system with other CareLink teams for deployment took considerable effort and coordination.

Thank you ;)