AGENT: Automated Guidance for Exercise and Therapy with Human Pose Estimation and Machine Learning

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AY 2021-2022 Second Semester

Introduction

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Introduction

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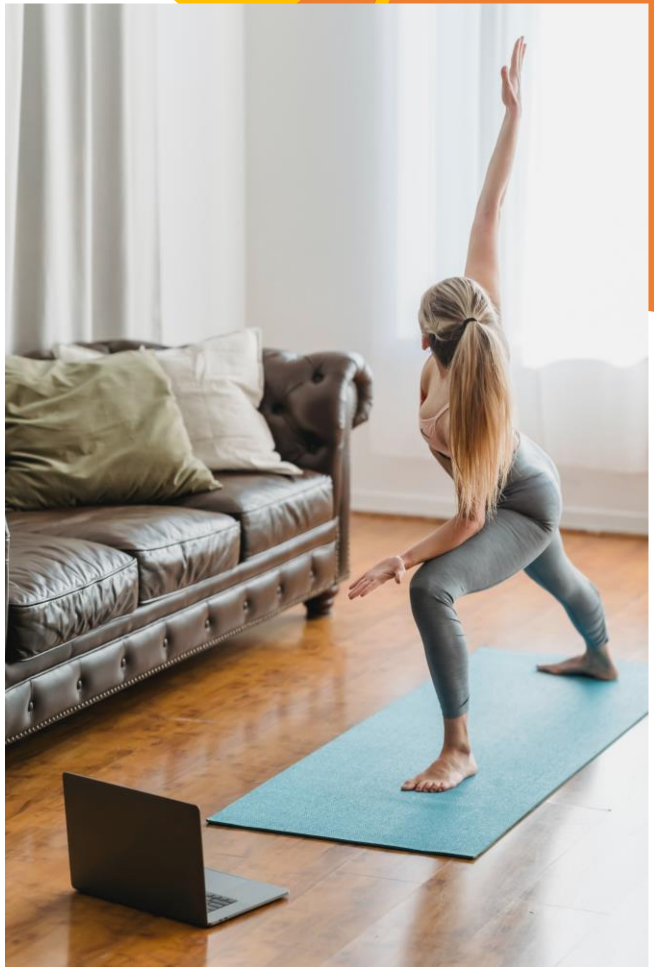

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Statement of the Problem

- Exercise Form Checker
- Most of these applications/systems require the use of a personal computer, webcam, and even a Kinect sensor
- **Develop a mobile-friendly exercise form checker application**
    - ✓Consume less space
    - ✓Almost everyone has a smartphone
    - ✓Easier to set up

Objectives

- Develop a mobile application as an exercise form checker using computer vision and machine learning
  1. Employ OpenCV and OpenPose for computer vision and human pose estimation while only using a single camera
  2. Train a machine learning model that identifies whether an exercise is performed correctly or not; and
  3. Develop a fitness learning application that can be used on mobile phones

Methodology – Development Process

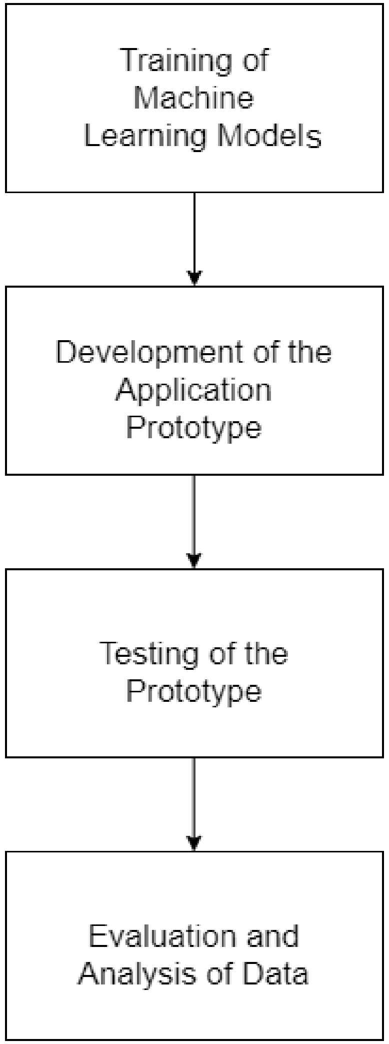


Fig 1: The Development Process

Methodology – Dataset

Video source: YouTube (Jeremy Ethier)

Video source: Darebee

Methodology – Dataset

Video source: Kaggle

Methodology – Machine Learning Models

__CNN-RNN Model__

- "general action recognition classifier" from UCF 101 – Dataset
- To identify if the appropriate exercise was uploaded for evaluation

__RNN Model (core feature)__

- Own dataset collected from YouTube, Kaggle, Darebee, and self-recordings
- To classify whether the exercise (squat) is correct or wrong

Methodology – Training of ML Models

- OpenPose
  - Human Pose Estimation library available in OpenCV Deep Neural Net module
- Returns the coordinates of 18 key points in the human body

```
net = cv.dnn.readNetFromTensorflow('graph_opt.pb') # Load the weights

inWidth = 368
inHeight = 368
threshold = 0.1

BODY_PARTS = { "Nose": 0, "Neck": 1, "RShoulder": 2, "RElbow": 3, "RWrist": 4,
               "LShoulder": 5, "LElbow": 6, "LWrist": 7, "RHip": 8, "RKnee": 9,
               "RAnkle": 10, "LHip": 11, "LKnee": 12, "LAnkle": 13, "REye": 14,
               "LEye": 15, "REar": 16, "LEar": 17, "Background": 18 }

POSE_PAIRS = [ ["Neck", "RShoulder"], ["Neck", "LShoulder"], ["RShoulder", "RElbow"],
               ["RElbow", "RWrist"], ["LShoulder", "LElbow"], ["LElbow", "LWrist"],
               ["Neck", "RHip"], ["RHip", "RKnee"], ["RKnee", "RAnkle"], ["Neck", "LHip"],
               ["LHip", "LKnee"], ["LKnee", "LAnkle"], ["Neck", "Nose"], ["Nose", "REye"],
               ["REye", "REar"], ["Nose", "LEye"], ["LEye", "LEar"] ]
```

OpenCV

Methodology – Joint Angles

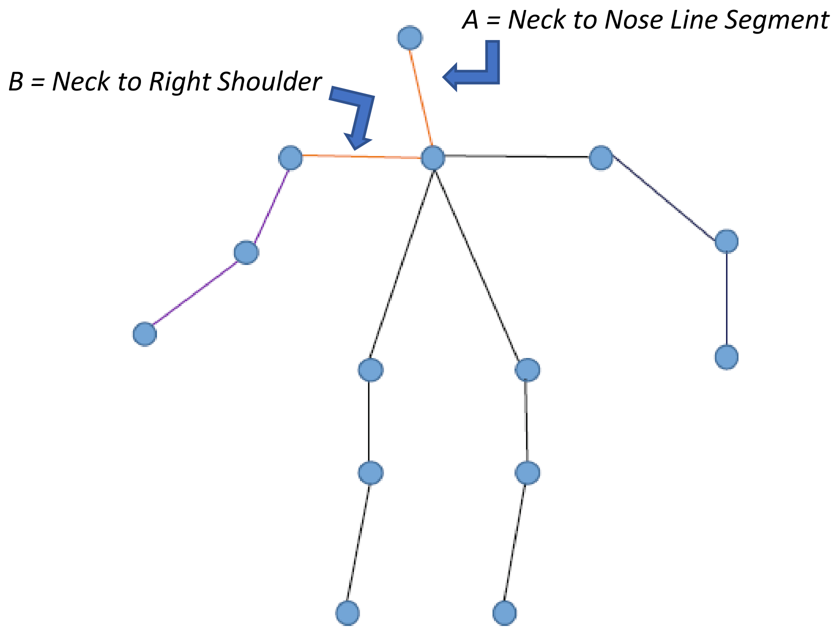


FIGURE 4: Schematic diagram of human skeleton.

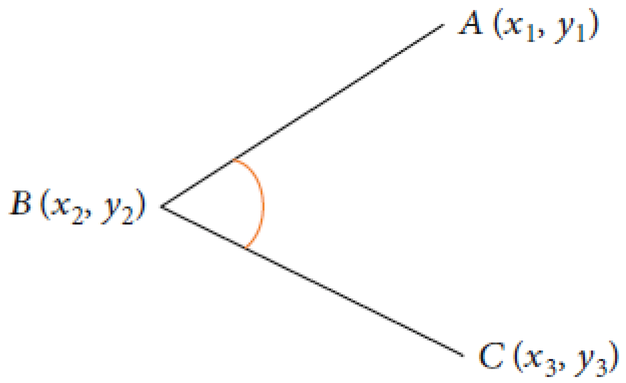


FIGURE 5: Schematic diagram of human skeleton.

Images taken from the study conducted by Zhu (2021)

Methodology – Joint Angles

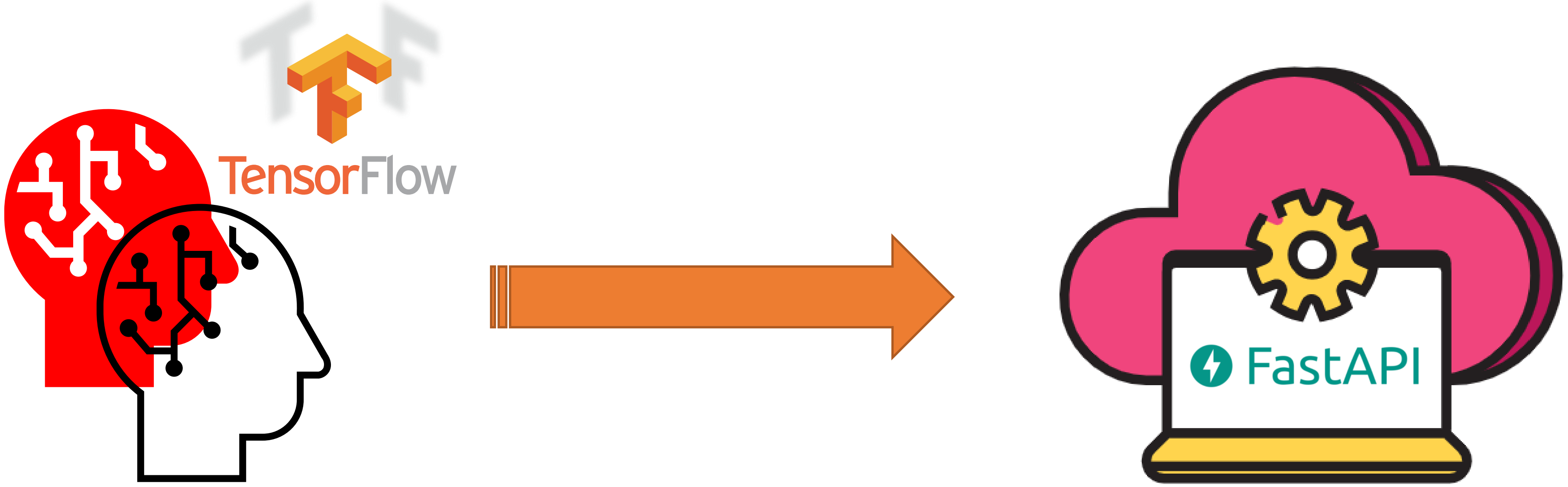
$$\overrightarrow{AB} = (x_2 - x_1, y_2 - y_1) \qquad \overrightarrow{BC} = (x_3 - x_2, y_3 - y_2)$$

$$|AB| = \sqrt{\left((x_2 - x_1)^2, (y_2 - y_1)^2\right)} \qquad |BC| = \sqrt{\left((x_3 - x_2)^2, (y_3 - y_2)^2\right)}$$

$$\cos\angle B = \frac{\overrightarrow{AB} \times \overrightarrow{BC}}{\left|AB\right|\left|AC\right|}$$

The ‘Close Angle’ concept (Zhu, 2021)

Methodology – Machine Learning Models



Methodology – Application Pipeline

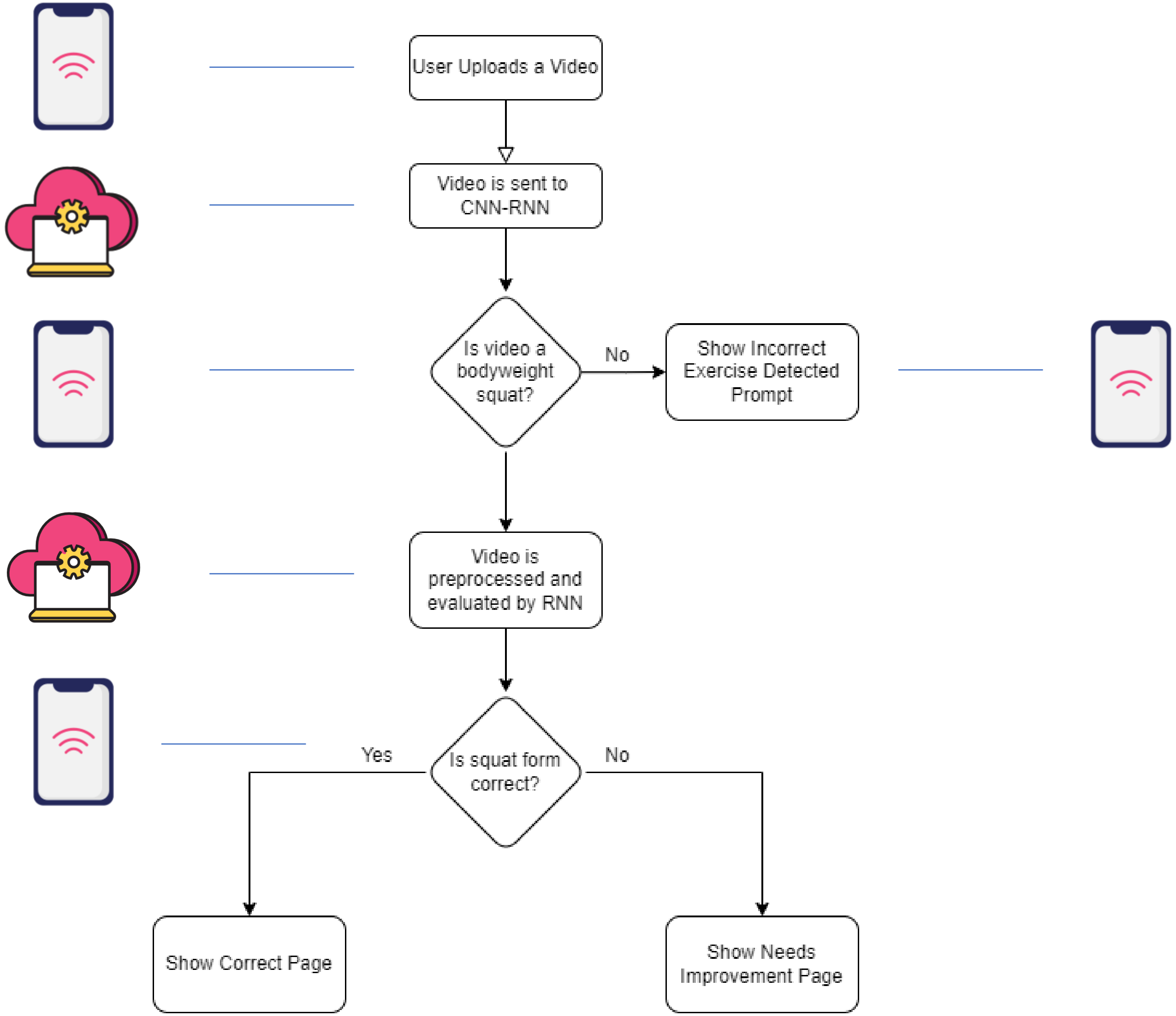
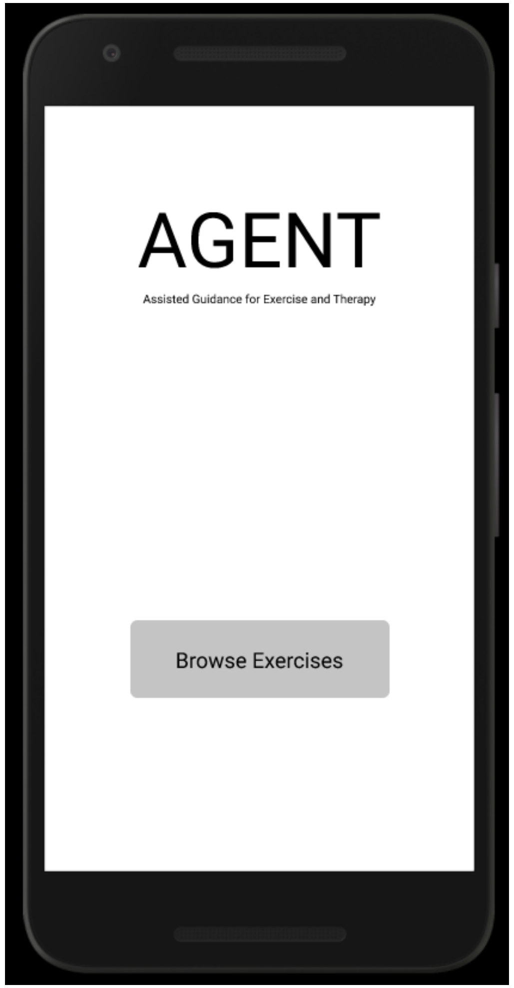
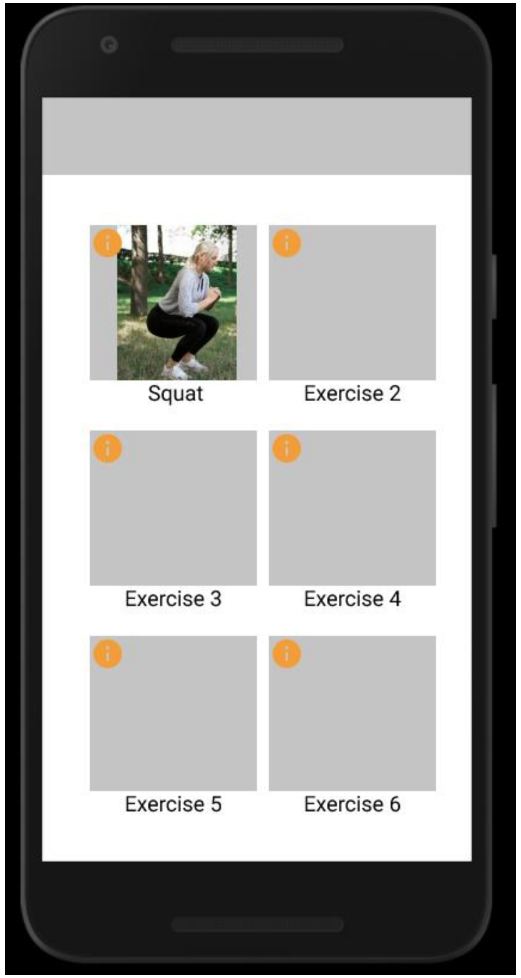


Fig 4: Application Flowchart

Methodology – Application Wireframes

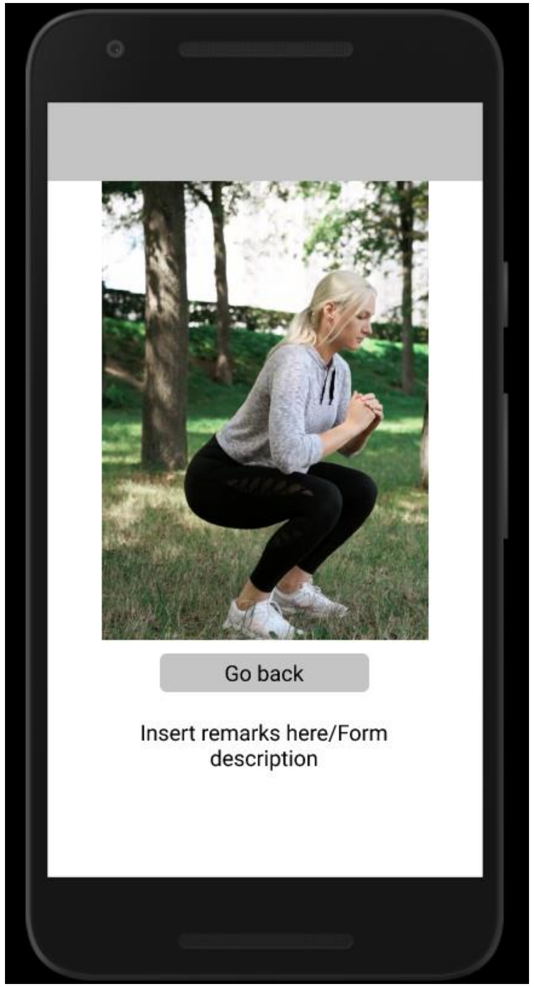
Figma Prototype

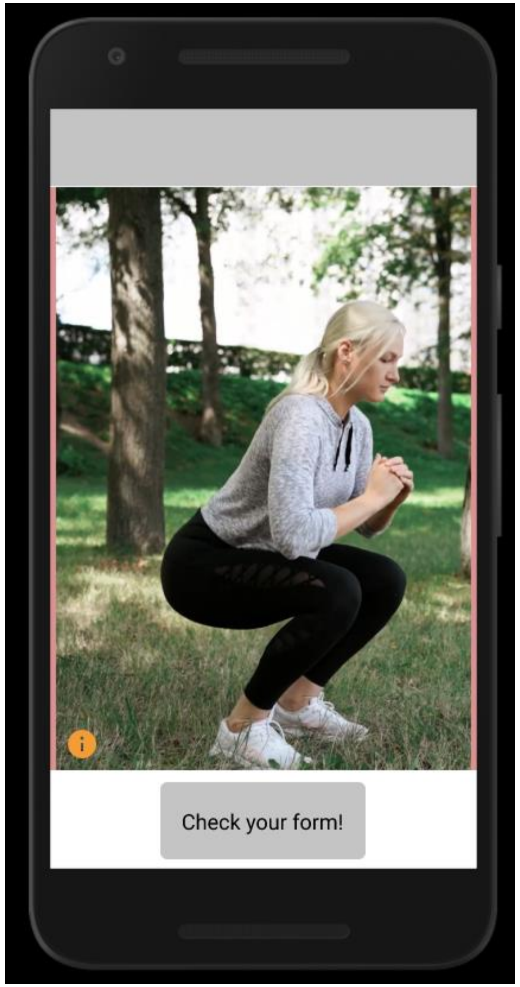




Methodology – Application Wireframes

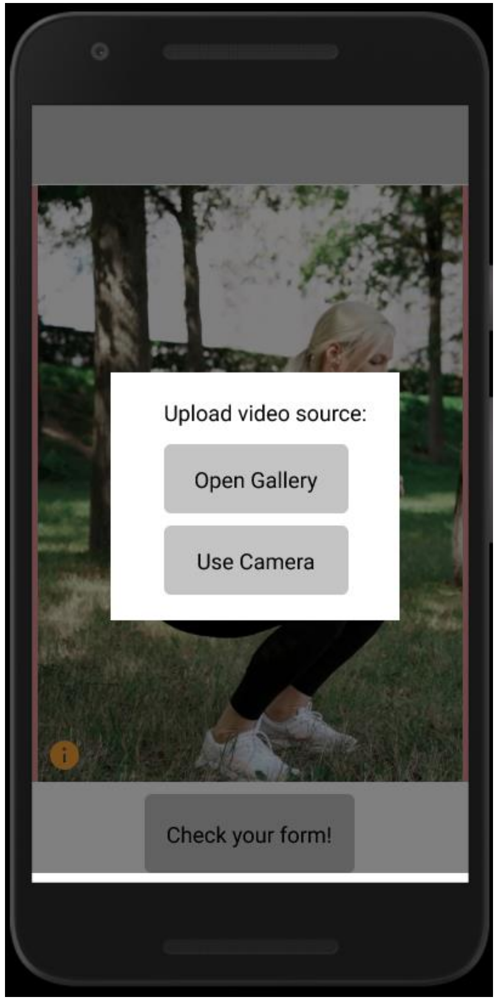
[Figma Prototype]

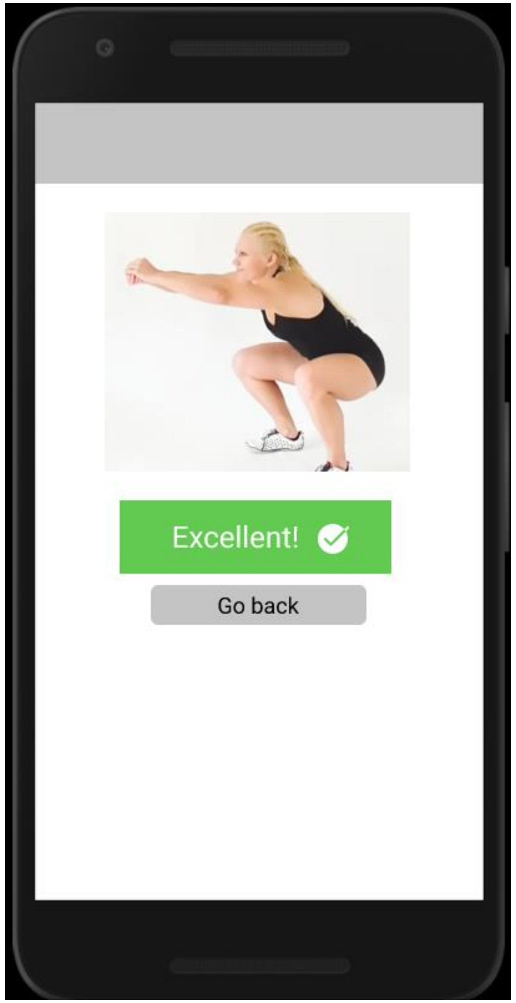


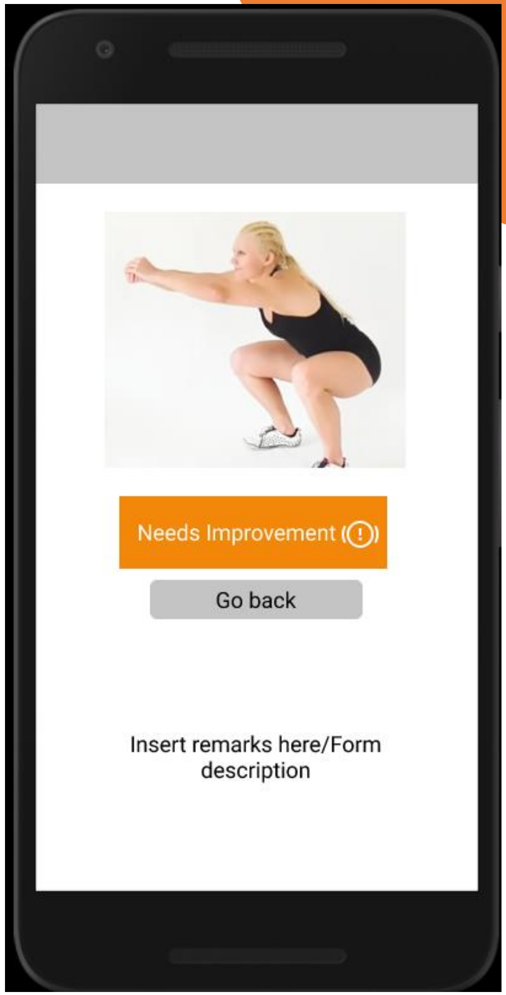


Methodology – Application Wireframes

[Figma Prototype]



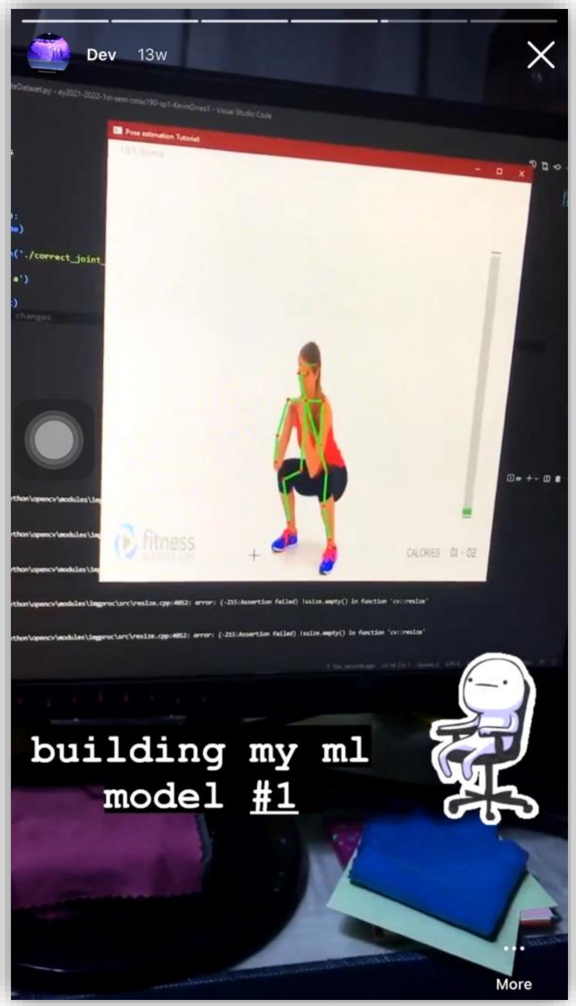




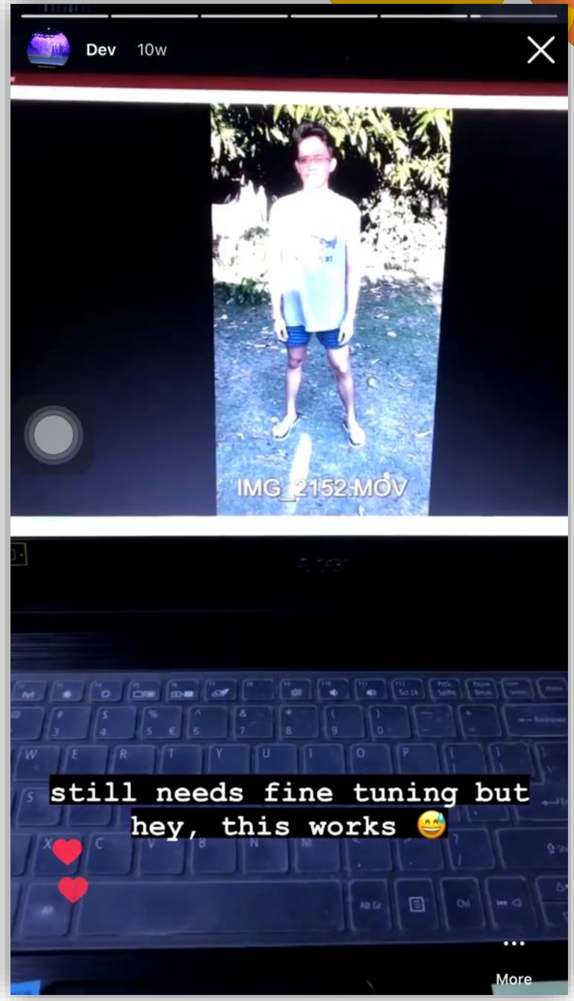
Results and Discussion – Dataset

Factors affecting human pose estimation accuracy

Results and Discussion – ML Model Training



RNN Model Training



CNN-RNN Model Training

Results and Discussion – ML Model Training

✓The CNN-RNN model was able to accurately classify all uploaded videos from the respondents as Bodyweight Squats

- RNN Model (31 videos from 15 respondents)
  - Model's accuracy = 71%
  - True positive rate/Recall = 65%
  - Precision = 79%
  - F-score = 0.71

TABLE I: Confusion Matrix for the RNN model

	Predicted 'Wrong'	Predicted 'Correct'	
Actual 'Wrong'	TN = 11	FP = 3	14
Actual 'Correct'	FN = 6	TP = 11	17
	17	14	

Results and Discussion – Mobile App

If you are using an Android phone, you may download Expo on your phone and access the app by scanning the QR code --->

Preview release channel "default"
Open the camera app on your device and scan the code below

https://youtu.be/hhKr1SfYUAk

Results and Discussion – Mobile App

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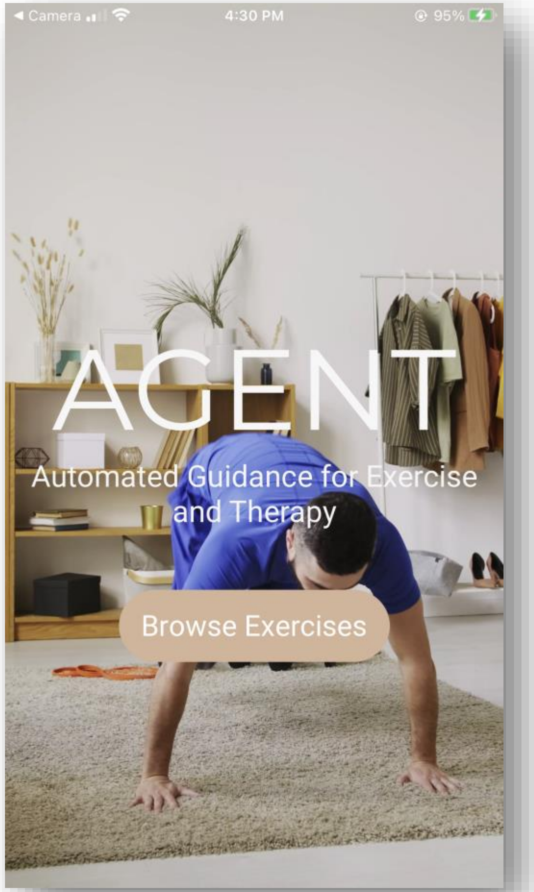
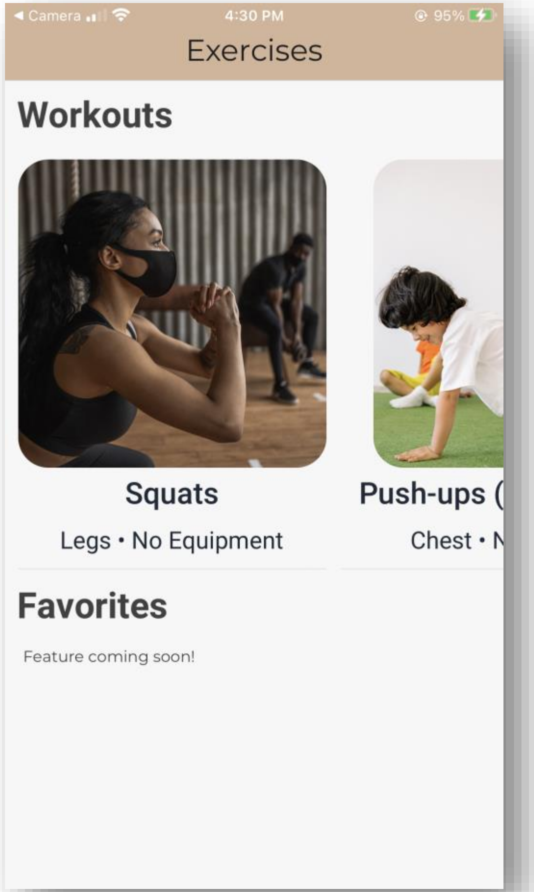
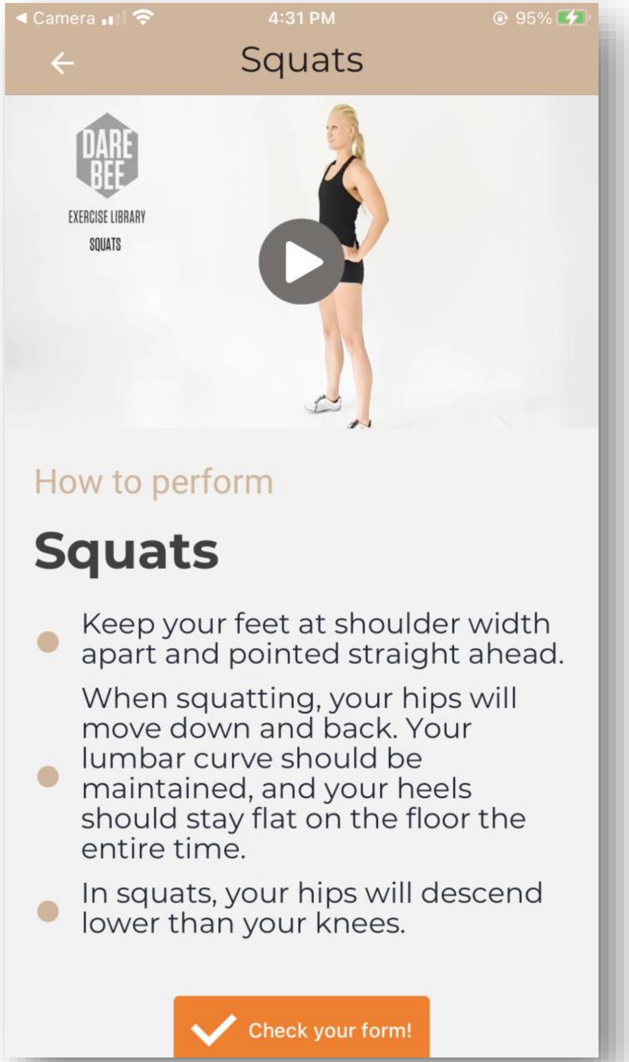
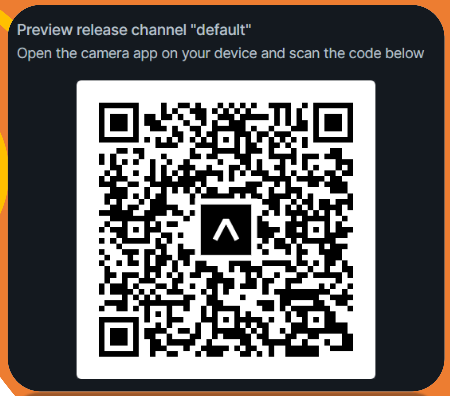




Screenshots are from iPhone 7 Plus iOS 15

Results and Discussion – Mobile App





Results and Discussion – Mobile App

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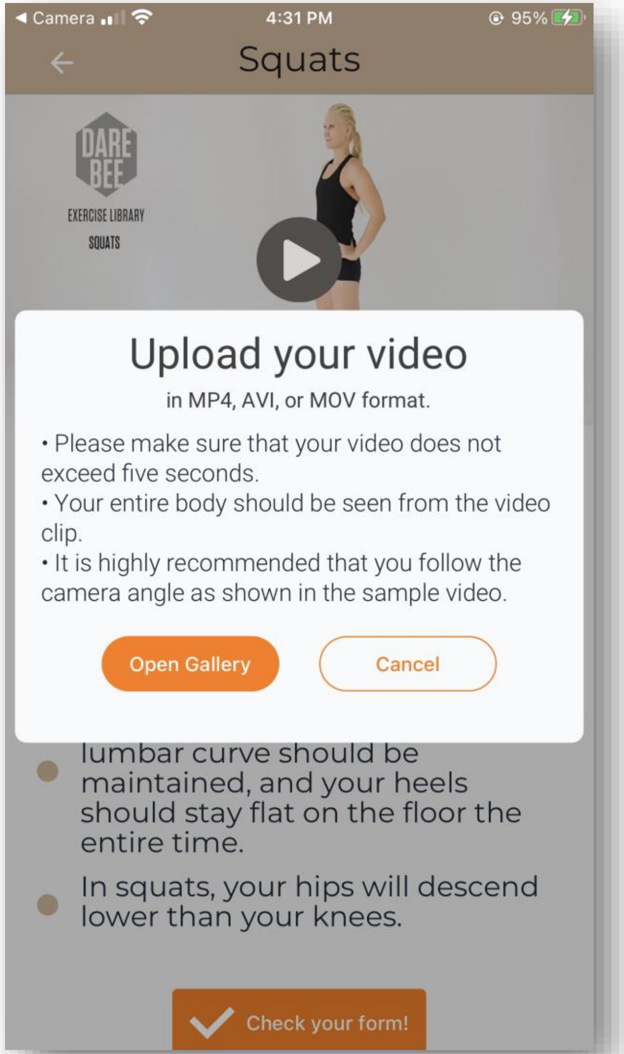

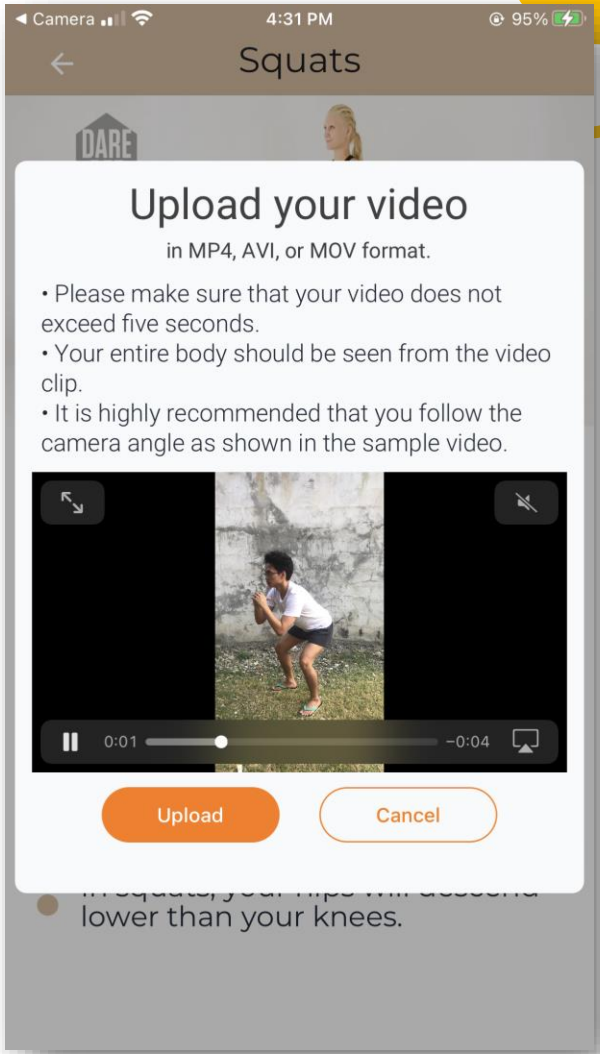

Results and Discussion – Mobile App

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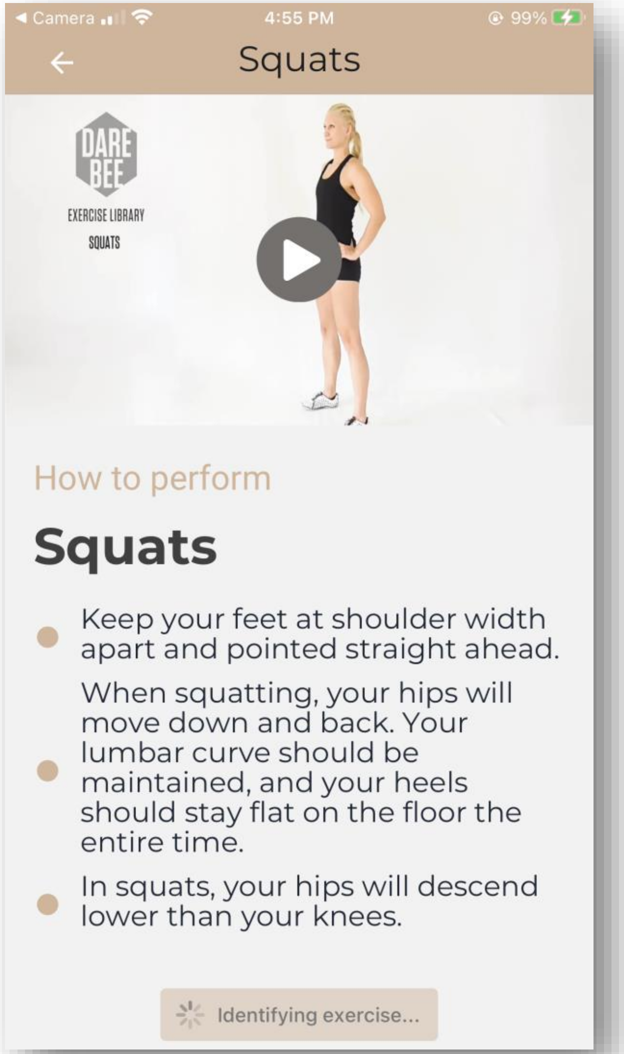

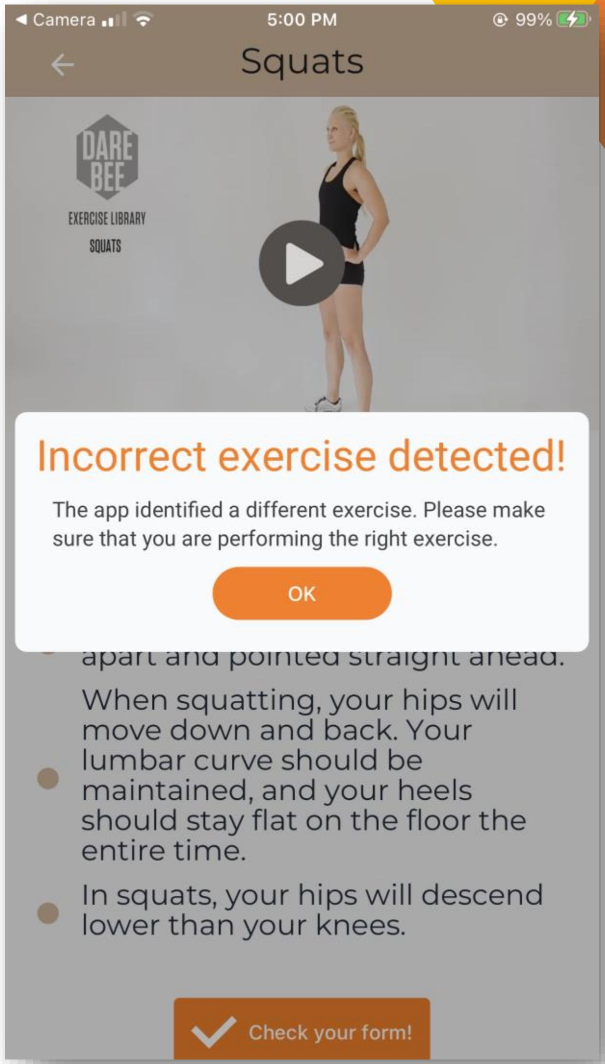

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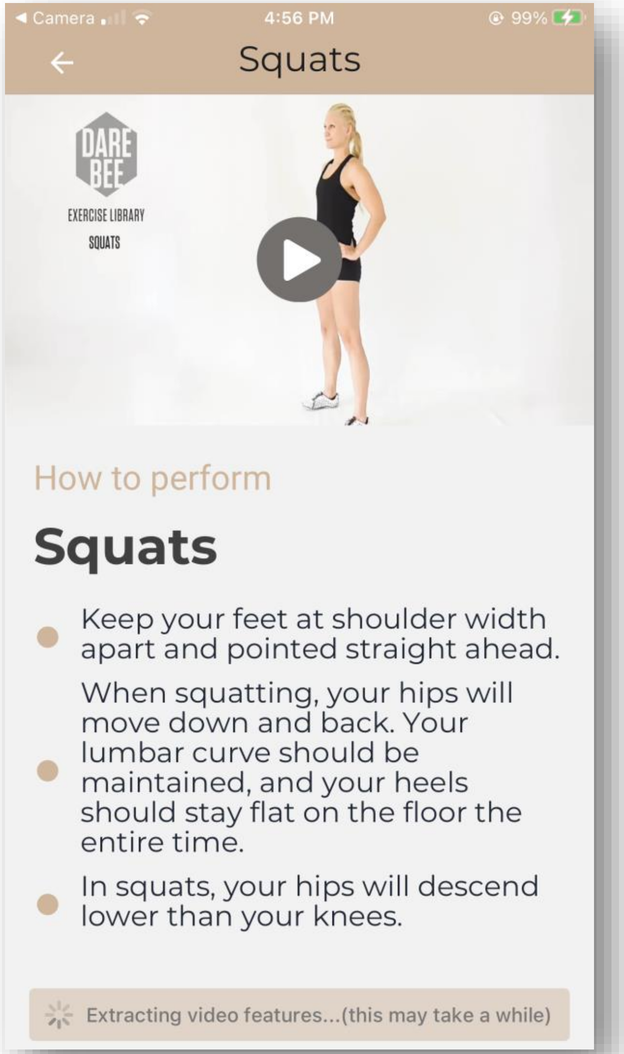

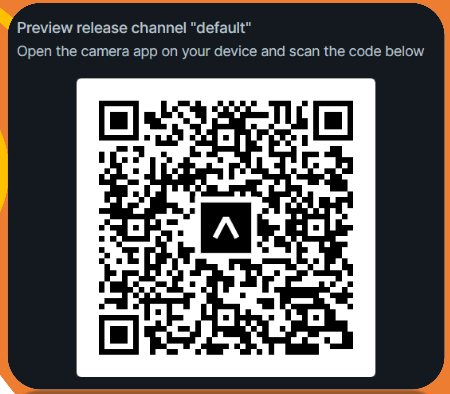

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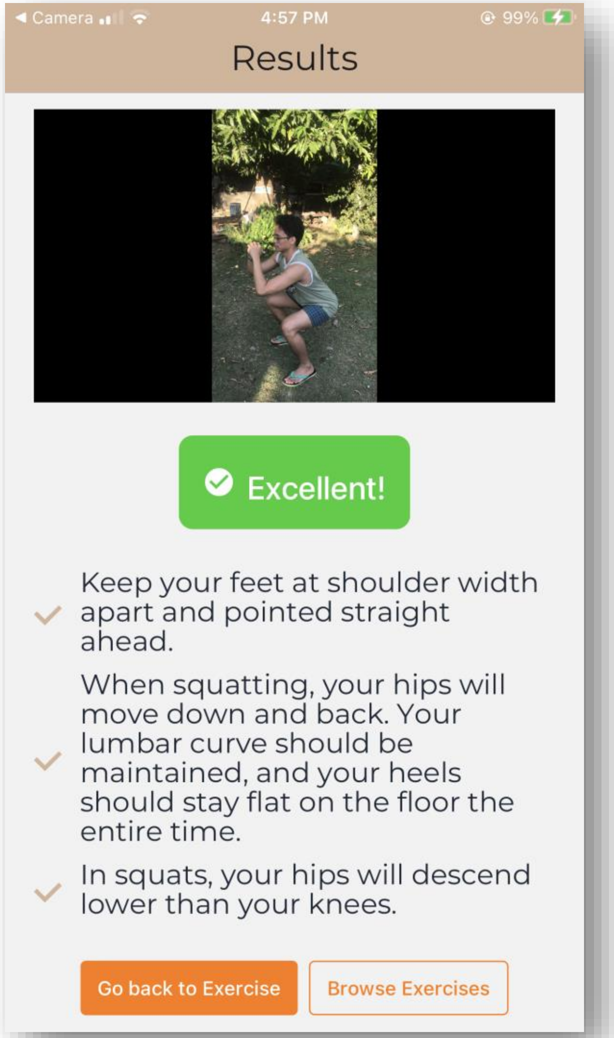

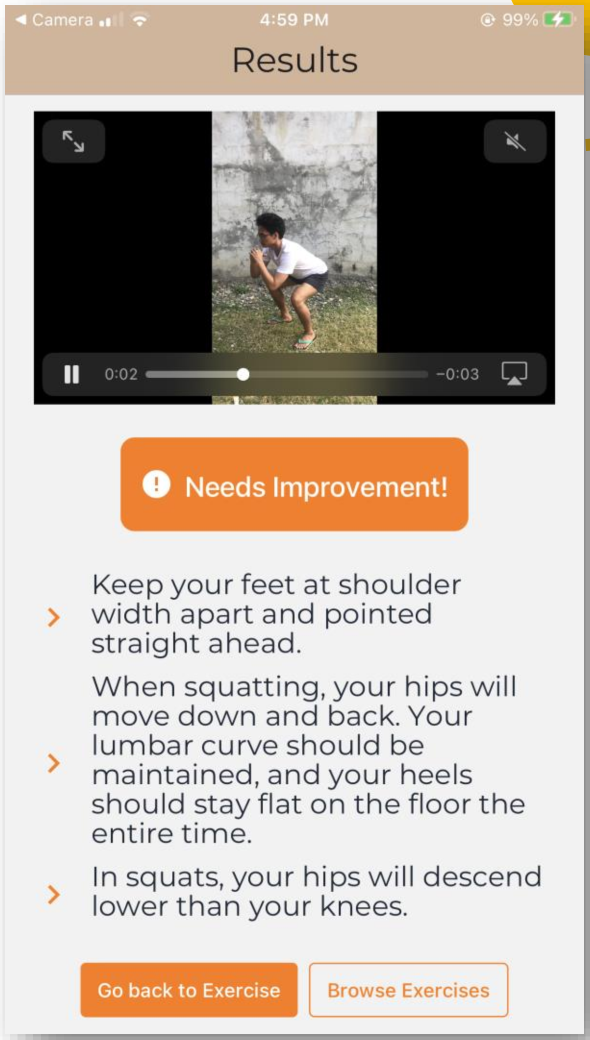

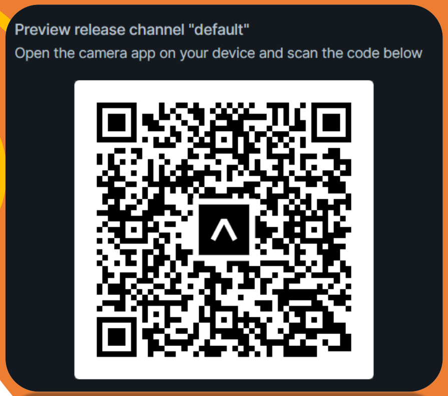

User Testing Results

- 47% of the 15 (mostly aged 20-23 y/o) respondents exercise regularly
- PSSUQ average scores for each question in each metric
  - System usefulness:
    - Best average score: 1.10
    - Worst average score: 1.71
  - Information quality:
    - Best average score: 1.13
    - Worst average score: 2.43
  - Interface quality:
    - Best average score: 1.33
    - Worst average score: 1.80

User Testing Results

- *“…you can consider trying to add yoga poses or meditation poses in order to expand your target users. “*
- *“AGENT is very sensitive to small details. 5 seconds is also very limiting. There are many exercises that take more than 5 seconds to perform. Pull-ups for example, especially for beginners might be a struggle…”*
- *“I think having a built-in camera app that can show a grid or bounding box to guide the user in positioning would help so that it can avoid errors in identifying the exercise. Minor concern: mas okay din kung may idle animation habang naghihintay ng analysis”*
- *“Identifying whether my form is proper took a bit of time…”*

Conclusions

✓Develop a mobile application as an exercise form checker using computer vision and machine learning

1. ☑ Employ OpenCV and OpenPose for computer vision and human pose estimation while only using a single camera
2. ☑ Train a machine learning model that identifies whether an exercise is performed correctly or not; and
3. ☑ Develop a fitness learning application that can be used on mobile phones

Future Work

- ❑ Build a larger dataset
- ❑ Optimize the algorithms used for video preprocessing
- ❑ Include other exercises and yoga poses as well

Thank you!

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