ADVANCED HCI - PROJECT

Part III

Alessandro Rizzetto

INJURY AND ACCIDENT PREVENTION TECHNOLOGIES

Injuries In Sports

The development of technologies dedicated to sporting activity is crucial in ensuring the safety and well-being of athletes, as well as enhancing the longevity of their careers.

Gym Injuries

Despite the benefits of regular exercise, there is always a risk of injuries for those who engage in physical activity. One common cause of injuries in the gym is poorly performed exercises

MY SOLUTION

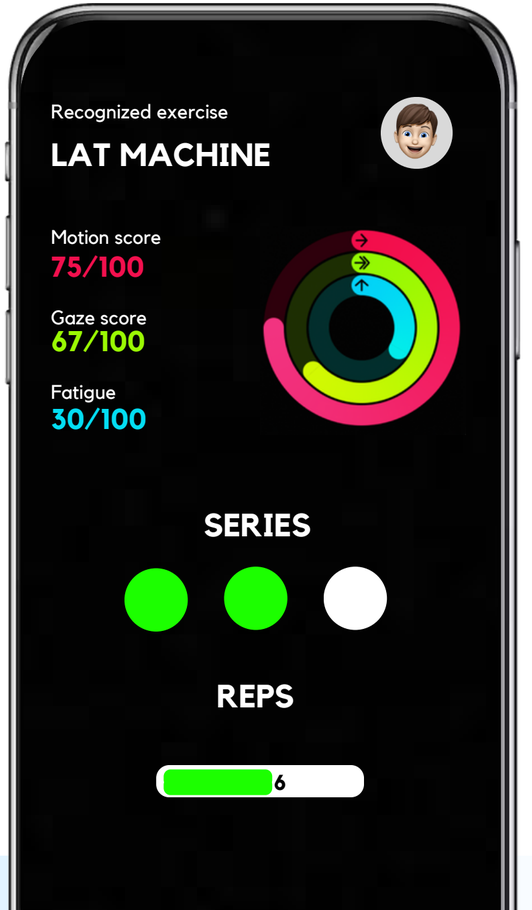
A smart assistant to train your body safely

A multimodal system capable of assisting athletes during the workout to ensure safety and effectiveness

Gesture is used for exercise recognition and their evaluation.

Gaze is detected to improve reliability and accuracy of the evaluation

Facial expressions are extracted to understand the intensity of the exercise



Alessandro

Age: 32
Location: Trento
Occupation: Personal Trainer
Level: Expert

DESCRIPTION

Alessandro has more than 10 years of previous experience in bodybuilding and is a competitive athlete. Managing large weights requires him to carefully control his workouts to avoid serious injuries or accidents

NEEDS

- Assess and improve weightlifting technique to avoid injury and optimize training.
- Monitor workload and intensity of workouts to avoid overloading and prevent injury.

GOALS

- Improve performance and get better and better results in bodybuilding competitions.
- Increase strength and muscle mass safely and effectively

Giovanni

Age: 25
Location: Trento
Occupation: Clerk
Level: Beginner

DESCRIPTION

Giovanni has never had significant experience with gym training and needs help getting started on the right foot and avoiding even the most trivial mistakes

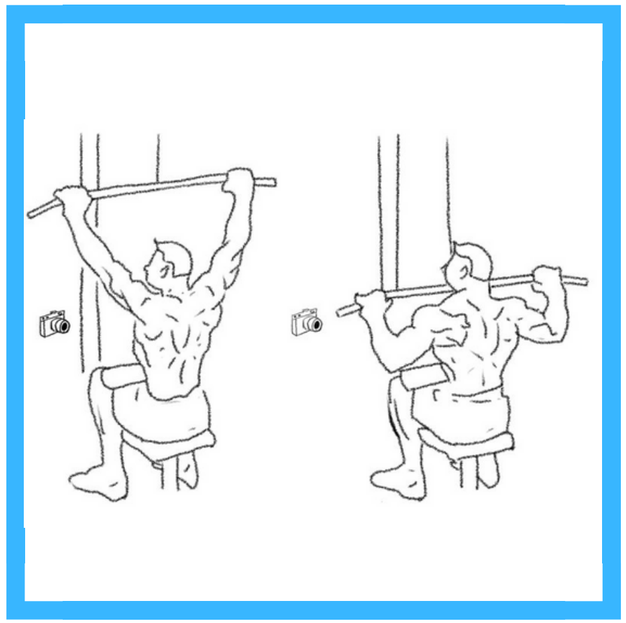
NEEDS

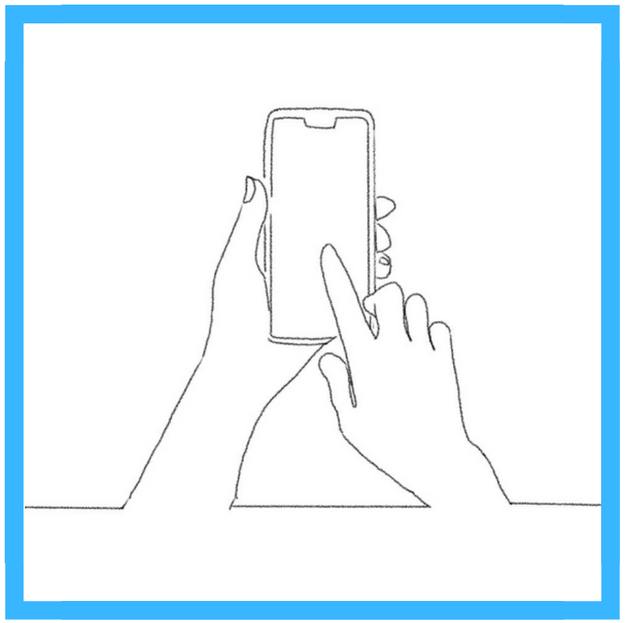
- Real-time feedback on body alignment and posture while performing exercises.
- Simple tips with a comfortable and intuitive interface

GOALS

- Learn proper training techniques to perform exercises safely and efficiently
- Preventing injuries and building a solid foundation for a future training program

THE SCENARIO





Possible stakeholders

- Athletes and fitness enthusiast
- Trainers and instructors
- Gym operators

- International Olympics Committee
- Physiotherapists
- Technology partners

- Equipment suppliers
- Certification bodies

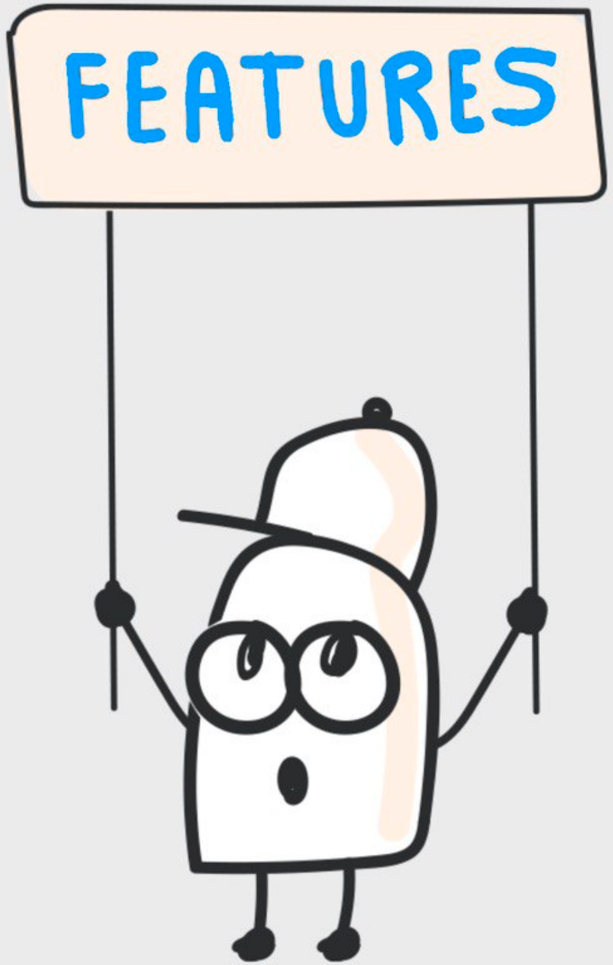
HARDWARE COMPONENTS

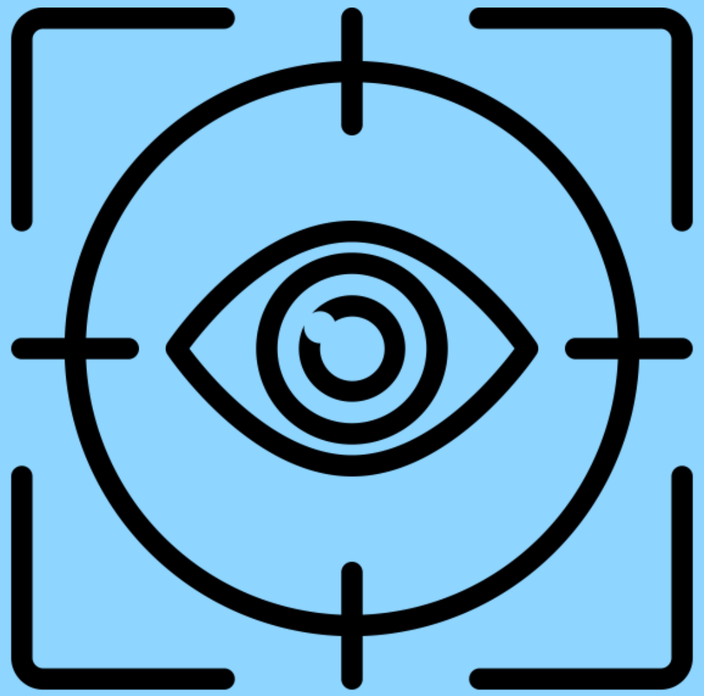
Resolution	1080p
Frame Rate	30fps
Min Focus Distance	0.5m
Max Focus Distance	2.5 m
H/V Field of View	75 degrees
Connections	USB

CPU	SoC quad-core Cortex-A72 64bit@ 1,5GHz*~ARM v8*~Broadcom BCM2711
Connectivity	2 x USB 2.0*~1 x MIPI DPI*~2 x USB 3.0*~1 x micro SD*~1 x MIPI CSI*~2 x micro HDMI*~1 x GPIO
RAM	8 GB
Power Supply	5 V

TOOLS FOR FEATURES EXTRACTION

- **MediaPipe** to infer pose and face landmarks
- Openface to extract gaze features and facial expression
- OpenCV to detect variations in facial color
- **Random Forest Classifier** to detect fatigue
- **Discriminant Analysis** to classify the physical exercise intensity





GAZE FEATURES

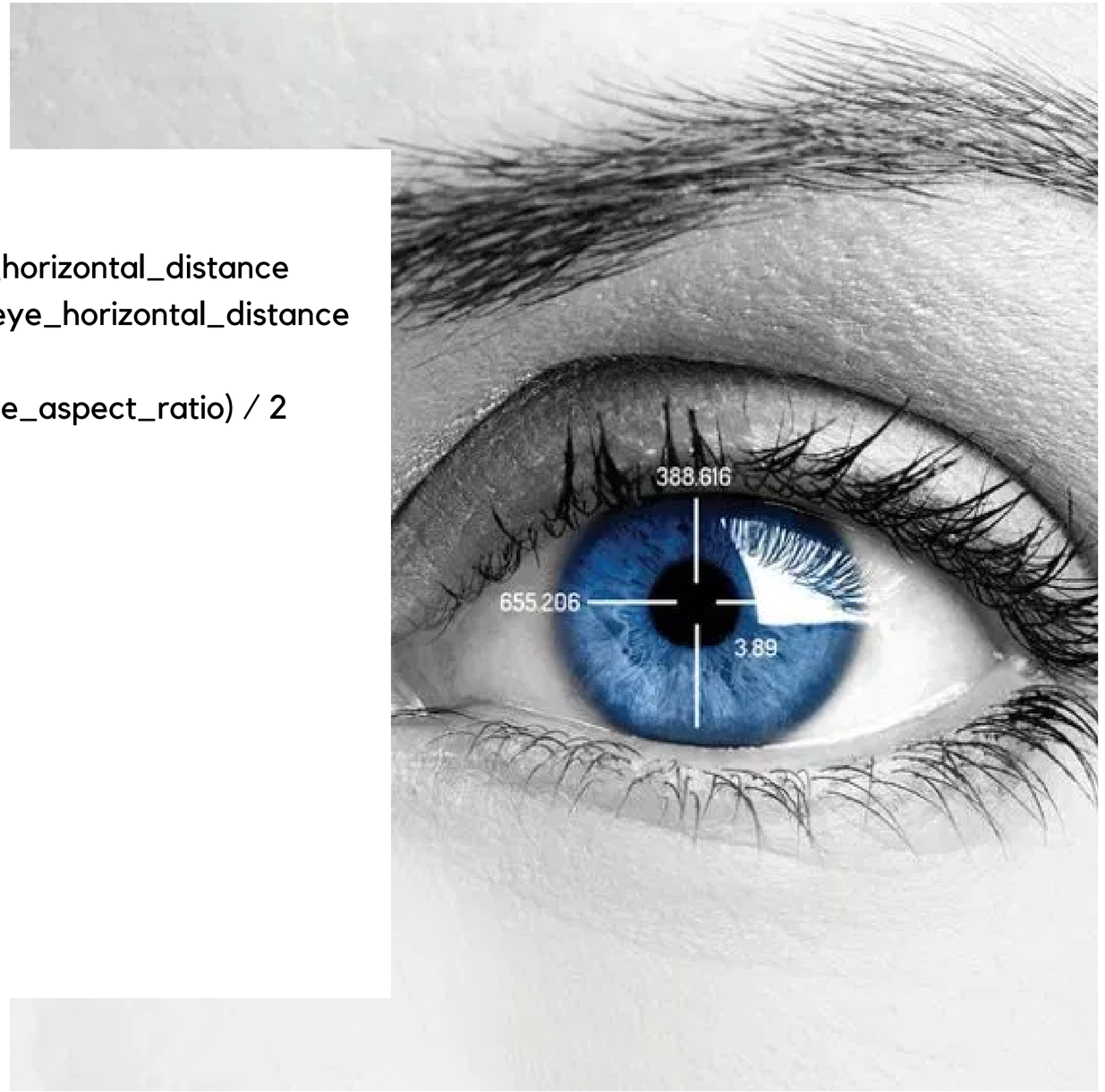
- Fixations duration
- Gaze direction
- Pupil size
- **Blinking rate**
- Gaze Heatmaps

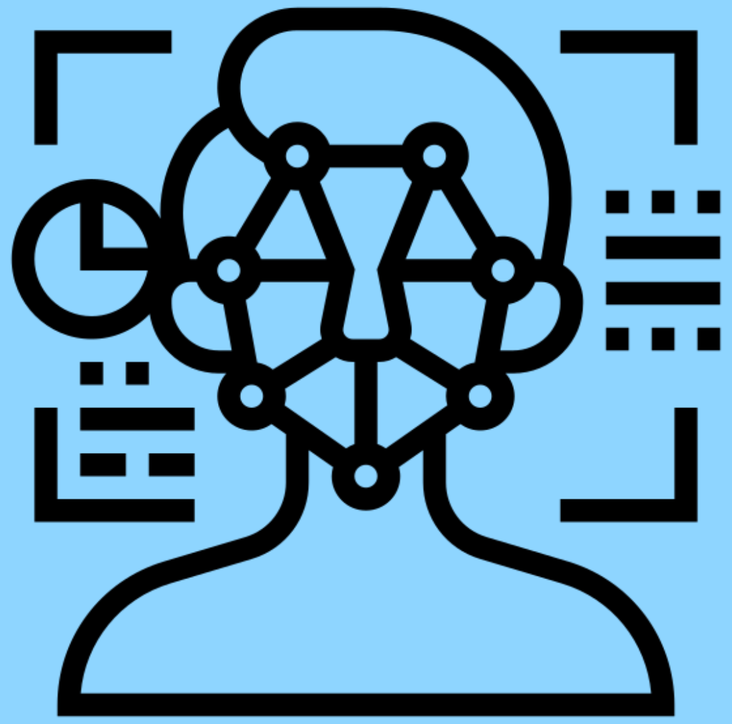
Openface

MediaPipe

BLINK DETECTION

```
# Calculate eye aspect ratio
left_eye_aspect_ratio = left_eye_vertical_distance / left_eye_horizontal_distance
right_eye_aspect_ratio = right_eye_vertical_distance / right_eye_horizontal_distance
# Calculate average eye aspect ratio
average_eye_aspect_ratio = (left_eye_aspect_ratio + right_eye_aspect_ratio) / 2
# Detect if eyes are closed
if average_eye_aspect_ratio < 0.2:
    if not eye_closed: #if eyes were open before, start timer
        eye_closed_start_time = time.time()
        blink_counter += 1
    eye_closed = True
 else:
    if eye_closed:
        eye_closed_duration = time.time() - eye_closed_start_time
        blinks_times.append(eye_closed_duration)
    eye_closed = False
```





FACIAL EXPRESSION FEATURES

- Action Units (AUs)
- Mouth shape
- Facial Landmarks
- AUs intensity
- Face color

MediaPipe

OpenCV

FACE COLOR

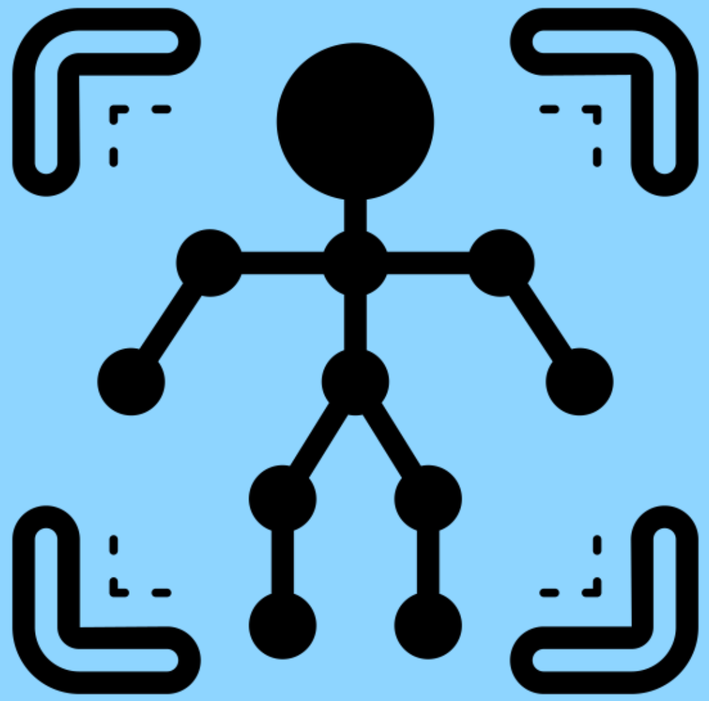
```
def is_face_red (frame, results, base_red, base_green, base_blue):
    # select the landmarks of the face
    face_landmarks = results.face_landmarks.landmark
    x_coords = [int(landmark.x * frame.shape[1]) for landmark in face_landmarks]
    y_coords = [int(landmark.y * frame.shape[0]) for landmark in face_landmarks]
    #create a mask with the same shape of the frame
    mask = np.zeros(frame.shape[:2], dtype=np.uint8)
    #fill the mask with the face landmarks coordinates
    cv2.fillPoly(mask, [np.array(list(zip(x_coords, y_coords)))], (255, 255, 255))
    #calculate the mean color of the face in the frame using the mask created before
    mean_color = cv2.mean(frame, mask=mask)

    blue, green, red, _ = mean_color

    #check if the green and blue values of the face are unless 40 points lower than the base color (the face is red)
    if (base_green - green) > 40 and (base_blue - blue) > 40:
        return True, red, green, blue

    #check if the mean color of the face is red
    if red > 150 and green < 100 and blue < 100:
        return True, red, green, blue

    else:
        return False, red, green, blue
```



GESTURE FEATURES

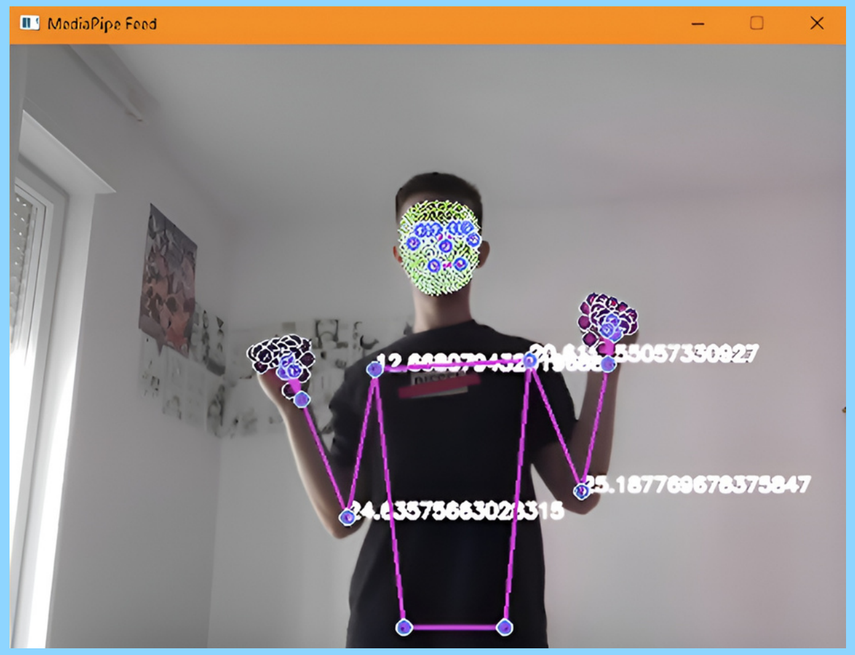
- Joint extension
- Bounding volumes
- Joint extension/angle/rotation
- **Joint angle relative to the body**
- Simmetry
- Amount of movement
- **Speed** and acceleration

JOINT ANGLES

```
def calculate_angle(a,b,c):
    a = np.array(a) #First
    b = np.array(b) #Mid
    c = np.array(c) #End
    radians = np.arctan2(c[1]-b[1], c[0]-b[0]) - np.arctan2(a[1]-b[1], a[0]-b[0])
    angle = np.abs(radians*180.0/np.pi)

    if angle > 180.0:
        angle = 360-angle

    return angle
```



JOINT ANGLES

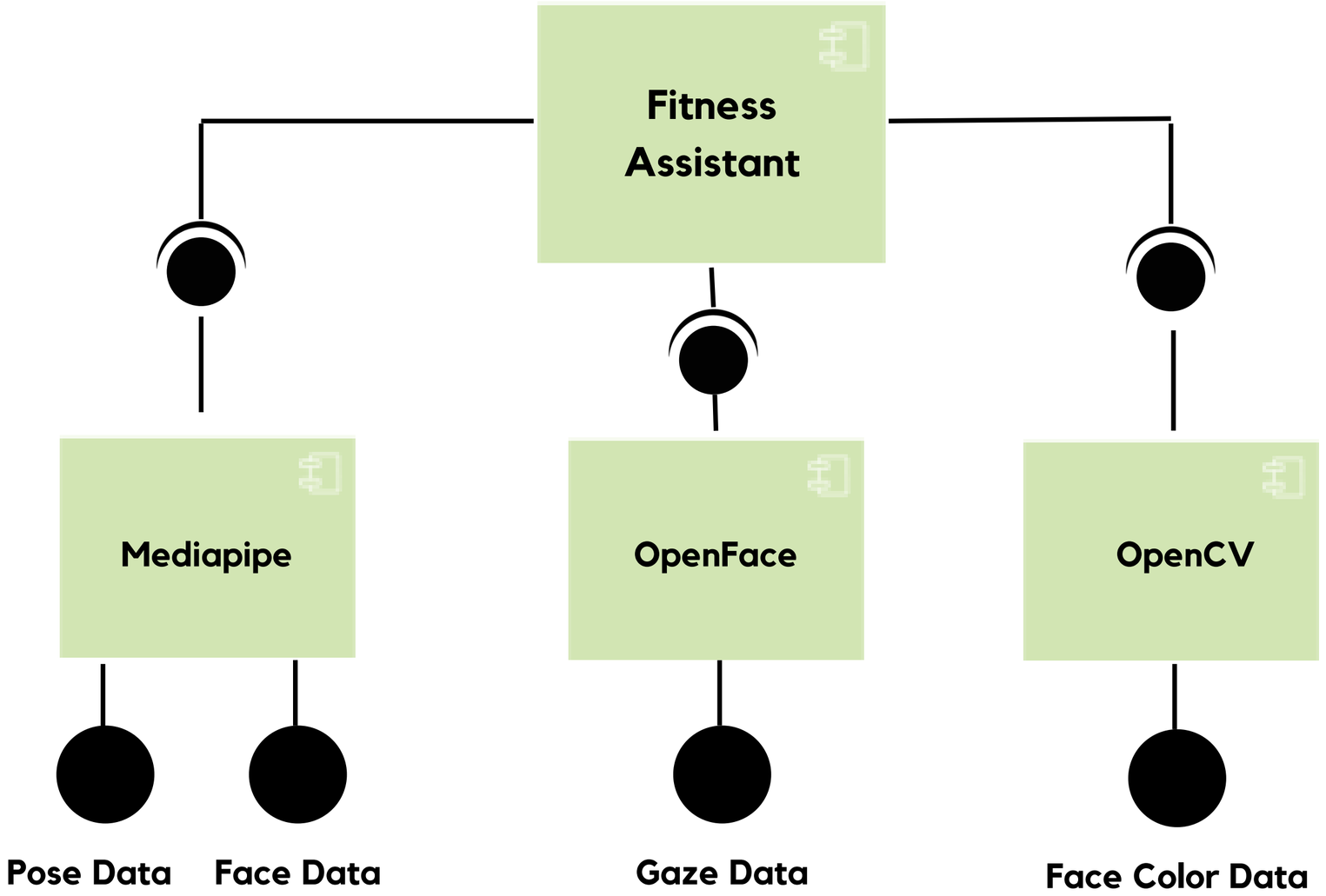
Score: 20.0

Score description: Right timing - Left timing - Up coordination - Down coordination - Right wrist angle - Left wrist angle - Right elbow max angle - Right elbow min angle - Left elbow max angle - Left elbow min angle - Right arm max angle - Right arm min angle - Left arm max angle - Left arm min angle
Correct coordination for up movement
Correct coordination for down movement

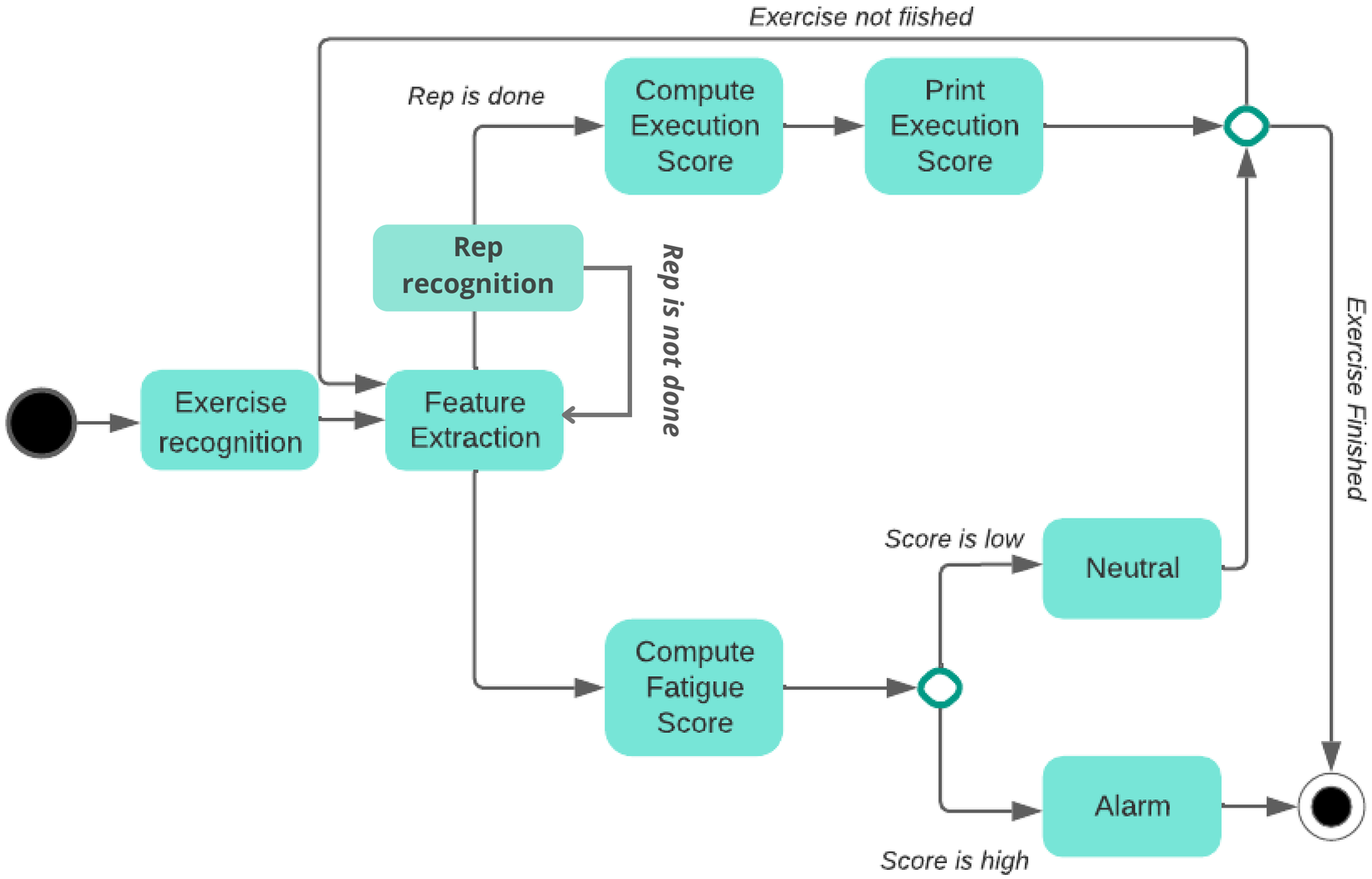
Score: 65.0

Score description: Right timing - Left timing - Up coordination - Down coordination - Right wrist angle - Left wrist angle - Right elbow max angle - Right elbow min angle - Left elbow max angle - Left elbow min angle - Right arm max angle - Right arm min angle - Left arm max angle - Left arm min angle
Correct coordination for up movement
Correct coordination for down movement

UML COMPONENT



UML STATE CHART



Data Unitizing

- Interval Coding
- Moving window
- Feature Extraction

Manage Errors

- Input validation to adapt functions according to input data

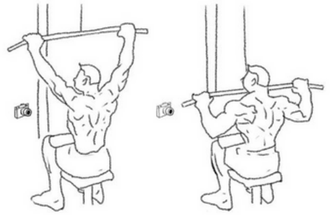
ASPECT AND ARCADE

- **Tutorial** explaining how to use and configure the application
- **Vignettes** applied on the machines indicating what to do and how to solve possible malfunctions
- **Combine and compute**, if excessive fatigue is detected this is immediately communicated to the user via the smartphone speakers
- **Audible feedback** communicates the status of the connection between the smartphone and the machine

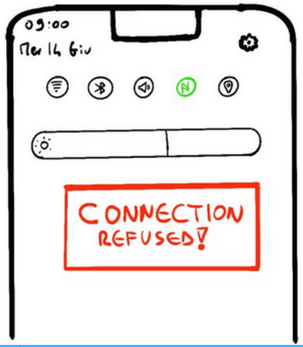
ASPECT AND ARCADE

PUT HERE YOUR SMARTPHONE

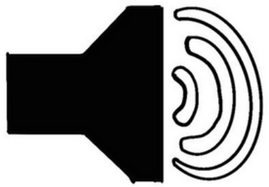
START YOUR TRAINING



IF THE CONNECTION DOES NOT TAKE PLACE, CHECK THAT YOU HAVE SWITCHED ON THE NFC

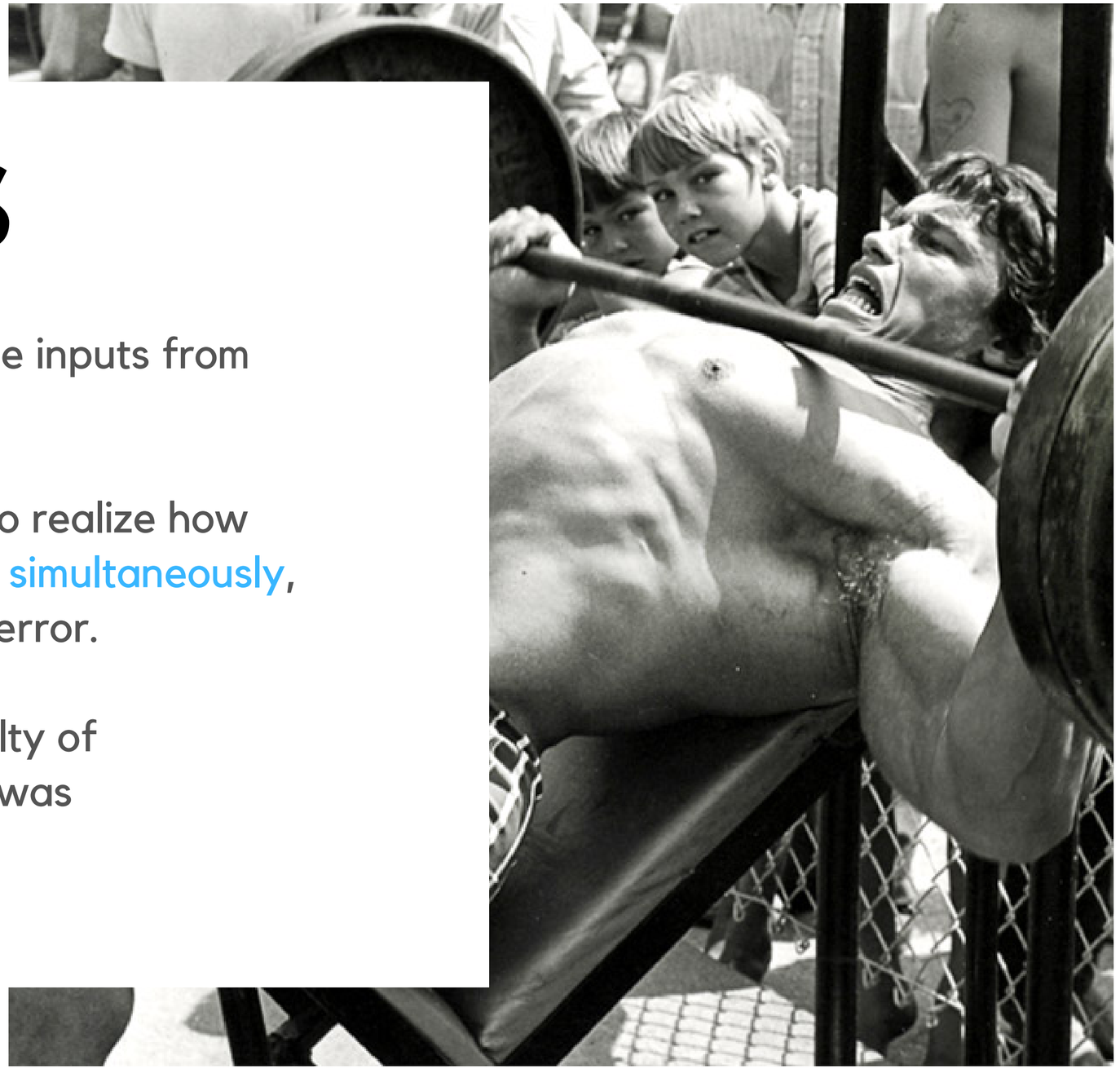


REMEMBER TO TURN UP THE VOLUME OF THE PHONE TO RECEIVE AUDIBLE ALERTS



CONCLUSIONS

- The training assistant is able to combine inputs from different modalities effectively.
- Implementing the project allowed me to realize how useful it is to rely on several modalities simultaneously, both for a better result and to reduce error.
- At the same time, however, the difficulty of coordinating a large number of inputs was demonstrated.



THANK YOU!

References

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