Re:Form – A Real-Time, Smart, Exercise-Form Monitoring System

FH10: Michael Chen, Tianda Huang, Udai Jain, Hannah Lee, Rishi Ponnekanti, and Ishan Shah

Faculty Mentor: Dr. Seth Bank | April 24, 2023

The University of Texas at Austin
Chandra Department of Electrical and Computer Engineering
Cockrell School of Engineering

ABSTRACT

Correct form is essential in athletic activities and physical therapy to prevent injuries and to see the desired gains in improvement. However, there are multiple metrics that are necessary to characterize form that are not visible by sight alone. To address this need, our project, Re:Form, uses an array of sensors and a phone application to collect information about a user's form and provide valuable feedback, specifically in the weightlifting industry. Re:Form accomplishes this using three primary components: (1) a feet pressure pad, (2) two barbell sensor attachments, and (3) a pose estimation model using phone camera data as input. Overall, through these, Re:Form is able to successfully provide informative feedback on a user's form.

PROBLEM DEFINITION

- **Design Problem:** Correct form is crucial for many activities, from sports to physical therapy, in order to **prevent injuries** and lead to the **desired improvements**. However, it can be **difficult to examine all the metrics of form by sight alone**.
- **Goal**: Our project, **Re:Form**, seeks to **fill this need** by using a variety of sensors to collect information on the user's form, process this data, and provide feedback on the user's form in a **meaningful, digestible way**.

- **Target Audience:** trainers & experienced weightlifters
- **Requirements:**
  - Quick turnaround time for feedback
  - User-friendly
  - Accurate for different genders, races, & body types

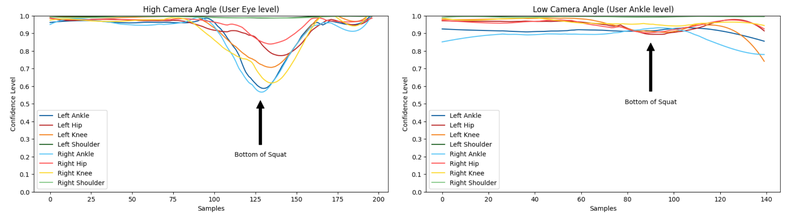
Table 1. Key Performance and Environmental Specifications

Input	Data Turn-Around Time	< 1 rest period between sets
	Data Arrival Time	< 1 duration of the set
Output	Form Estimation/ Sensor Accuracy	> 75%
	Sensor Signal-to-Noise Ratio (SNR)	> 40 dB
Operating Environment	Temperature	65°F to 80°F
	Humidity	30% to 50%

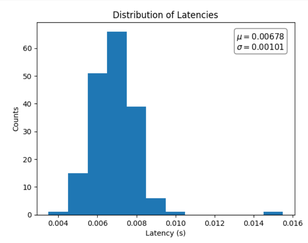
TESTING AND EVALUATION RESULTS

- Overall, Re:Form **works really well** for its intended purpose, providing feedback and data on multiple aspects of form.
- We tested all three primary components **individually and together**.
- **Potential Improvements:** additional filtering, higher resolution in foot pressure pad, even higher confidence levels in pose model

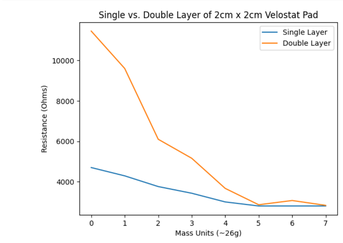
A **low camera angle results in better performance** in the pose estimation model than a high camera angle.



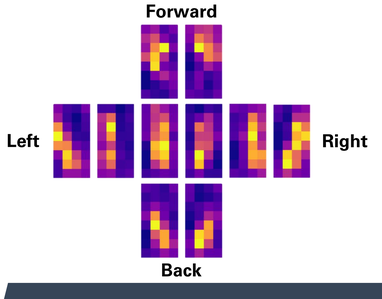
Re:Form is **consistently rapid** at collecting pose data.



Double layer Velostat has a **higher saturation weight** than single layer.



The feet pressure pad is capable of **detecting shifts in weight** in all directions.



The IMUs in the barbell sensors are fairly **accurate**.

Axis	Measured (LSb)	Measured (mgs)	Error (mgs)
Neg. X	8134	992.470	7.530
Pos. X	8212	1001.864	1.864
Neg. Y	8031	979.782	20.218
Pos. Y	8305	1013.210	13.210
Neg. Z	8142	993.324	6.676
Pos. Z	8266	998.184	9.658
Aggregate			
Mean	8182	998.184	9.658
Std. Dev	100	12.163	6.321

SUMMARY OF DESIGN

- Re:Form monitors the form of the user during a lift using **three main components**: (1) **the feet pressure pad** to measure the weight distribution placed on the user's feet, (2) **two barbell sensor attachments** to monitor the rotation and tilting of the barbell, and (3) **the pose estimation model** that uses the phone camera as input and is used to calculate the change in joint angles over time.
- These are all synthesized using an **iPhone application**, which displays the feedback in the form of a **replay video**. Through this, users can watch the change in feet pressure, the tilting and rotation of the barbell, and the joint angles over the duration of the lift. .

- **Steps for Use:**
  - **SET-UP:** A walkthrough is provided, clearly delineating the proper steps
  - **RECORD THE LIFT:** Users can start recording their lift.
  - **PROCESSING:** The sensor data is collected and processed.
  - **FEEDBACK:** Users can easily scroll through the feedback on their phone.
- **Characteristics:** User-friendly, timely, able to characterize form in many ways

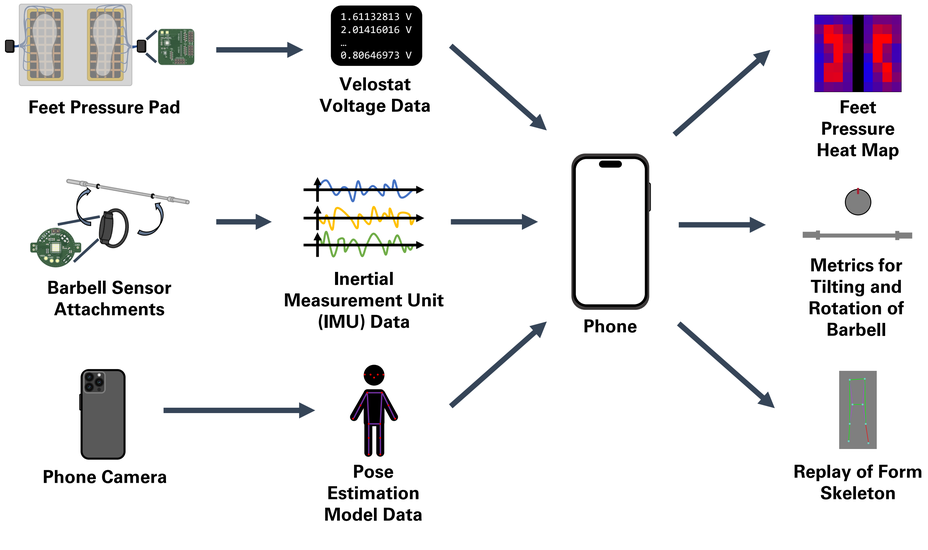


Figure 1. Block Diagram of Re:Form's Overall System.

- **Limitations:**
  - Works best with a solid-color background clear of objects and people, though it can still work in non-ideal settings
  - Only pose estimation model is real-time, though this functionality can be added to the other components

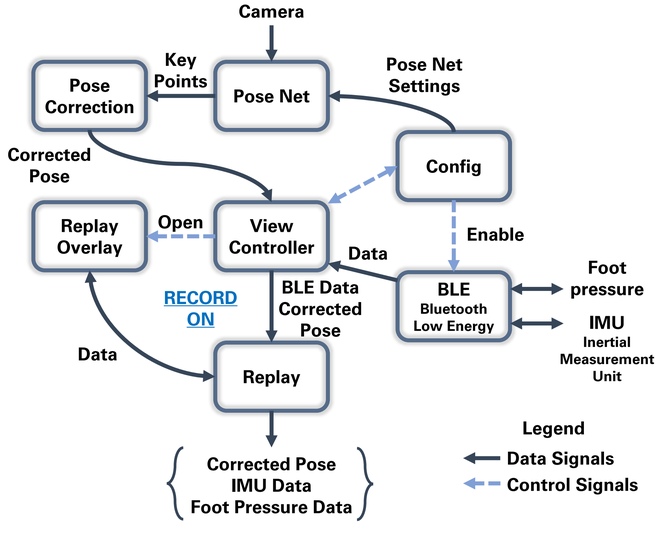


Figure 2. Software Block Diagram of Re:Form.

CONCLUSION

- **Takeaways:**
  - Re:Form is capable of collecting data on **multiple metrics of form**, many of which can be **difficult to gauge by sight alone**.
  - Re:Form focuses on **user-friendliness**, providing a **walkthrough** of the setup and **easily understandable feedback**.
- **Future Steps:**
  - Add the capability to evaluate **other types of lifts and forms of activity** (e.g. kicking a soccer ball, performing physical therapy movements, etc.)
  - Add more detailed **feedback on specific improvements** the user can make to their form