ECE1778 Final Report

TruMove

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Introduction

What: The goal of TruMove is to help people practice motor skills more effectively by instructing technique, measuring movement, and providing feedback.

Sport-Specific Instruction
TruMove instructs users to perform motor tasks that are specific to a sport or activity. For example, weightlifters may practice biceps curls to improve their technique, strength, and overall performance.

Movement Measurement
An external sensor, built from the Texas Instruments SensorTag, is used to measure body movement. The SensorTag is a 9-axis inertial motion sensor that can provide motion, position, and orientation data to TruMove. For example, the external sensor can track movement of the arms during biceps curls.

Results and Feedback
Following completion of a motor task, TruMove provides a user with knowledge of their performance. The app identifies areas for improvement and provides feedback for improving performance on subsequent trials. For example, TruMove can determine if a user is moving their arms too laterally during biceps curls and inform users to focus on reducing lateral deviations in ensuing trials. Real-time user feedback is provided using visual and auditory alerts from the smartphone. For example, when lateral movement exceeds a predetermined threshold, the user is alerted by an alarm from the smartphone.

Why: Technique is important in sports and exercise. Providing feedback on kinematics can accelerate motor learning and help prevent injury.

Motor Learning
Motor learning involves improving the smoothness and accuracy of movements (1). Motor skills are best learned through practice.

Kinematic Data
Kinematics provide valuable insights on movement to a level of detail that would otherwise be undetected (2).

Results and Feedback
Following motor practice, receiving knowledge of performance and results can enhance motor learning (3). As motor learners become aware of their errors during task performance, they can use this information to improve performance over the long term. Real-time feedback can also alert learners to make immediate adjustments and reinforce positive behaviours.

Errorless learning
Errorless motor learning is a form of implicit learning which involves strategies that reduce the number of outcome errors during practice (4). The learner inhibits the acquisition of explicit knowledge by reducing the number of error-correcting attempts to meet task demands. The skills acquired during errorless practice reduce the demand for explicit attentional resources to control movement and represent an implicit and robust mode of learning that is better protected against breakdown from distractions. Improving performance in the short term reduces errors and therefore promotes errorless learning in the long term.

Injury Prevention
Identifying negative movement patterns, no matter how miniscule, can help prevent injury before problems exacerbate. Asymmetries represent misalignments and can reflect increased vulnerability to injury (5).

Accessibility
Collecting kinematic data has traditionally depended on large and expensive motion capture equipment. The advancement of smartphones and sensors has given individuals a more accessible means of collecting this data.

Functionality

Menu
Users can select *Train* to begin practicing a sport. Training protocols are tailored to specific activities within their respective sports. For this prototype, we focused on biceps curls in the context of weightlifting. Users can also select *Stats* to review their performance history for specific activities.
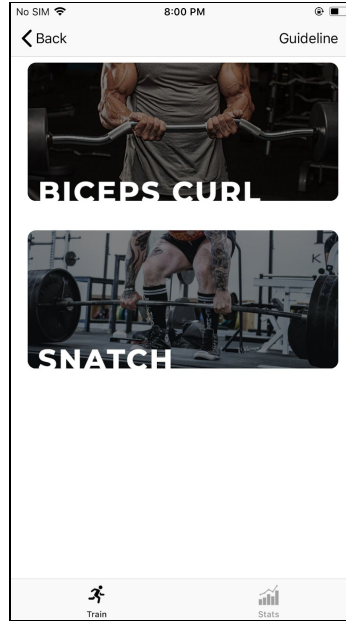
Guidelines

Prior to practicing an activity, users can review guidelines for optimizing their movement. The guidelines will pop out automatically for newly registered users. The rationale for these guidelines is also provided. Providing this context can help users retain this procedural knowledge better. This knowledge and reasoning becomes especially important for users who complete a variety of exercises with different guidelines.
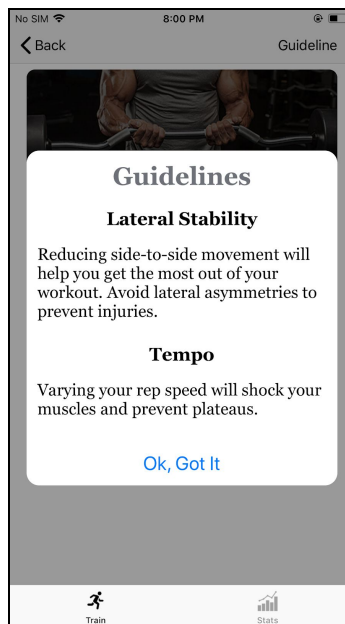
Instructions

Users are provided with detailed instructions on how to properly perform an activity. This information is supplemented by step-by-step diagrams that are easy to follow. They are also briefly prompted to check the sensor connection and follow the tempo guide in the next screen.
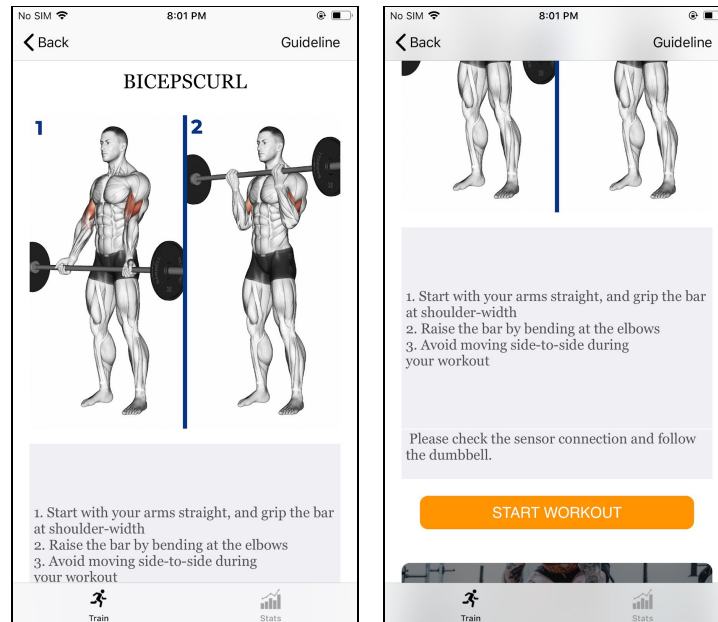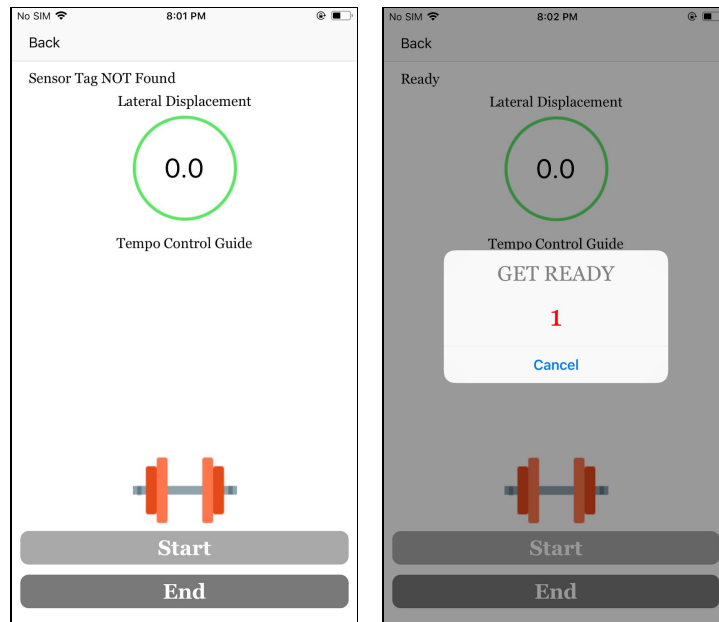

Practice

This screen is active while users practice a movement. The status of the sensor is provided, indicating whether it needs to be connected or is ready for use. Users can select *Start* to begin an exercise and are then given five seconds to move into the starting position.

During a live practice session, the animated dumbbell oscillates vertically to indicate the recommended repetition speed. The intent is for users to match their vertical movements with the animated dumbbell. The repetition speed varies from set to set to promote variable tempo. Varying the tempo can help maximize performance gains and prevent muscle plateaus.

Real-time feedback is provided with both visual and auditory alerts. Lateral acceleration is measured from the user's side-to-side movements and is displayed in the circle. The circle remains green when a user's lateral stability is maintained at a appropriately minimal amount. When a user exceeds a certain threshold of lateral acceleration, this circle turns red and an alarm sounds. These alerts prompt a user to make repetition-by-repetition adjustments, if necessary.

Feedback - Lateral Stability

After practicing an activity, users are given feedback on their lateral stability. This feedback includes their lateral acceleration, as well as a stability score ranging from one to ten. This stability score makes it simpler for users to track progress over time, much like a game. If a user's lateral stability is within an appropriate range, TruMove encourages similar performance in subsequent practice. TruMove can detect if a user is deviating in a certain direction and provide further recommendations based on that information. For example, TruMove can detect when lateral acceleration is negative and will notify the user to reduce this asymmetrical movement in subsequent practice. The importance of controlling these side-to-side movements is also described.
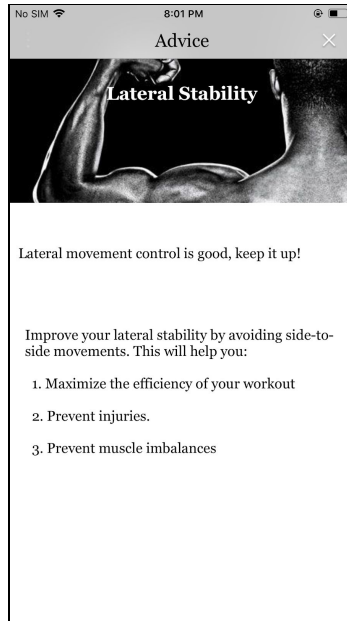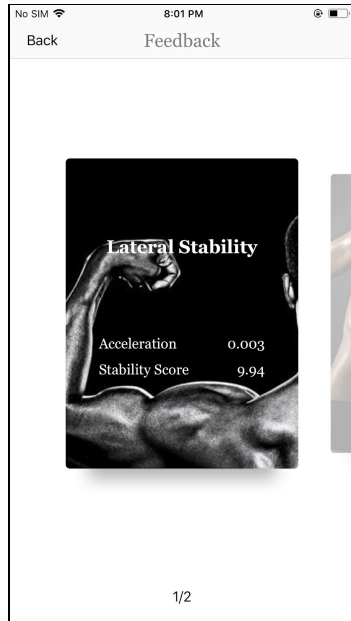
Feedback - Tempo

TruMove can detect when a user has been maintaining the same tempo throughout consecutive practice sessions and will instruct users to move faster or slower in following set, depending on their recent history. The importance of varying tempo is also described.
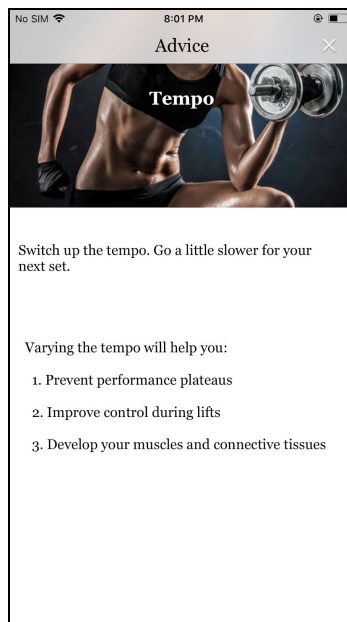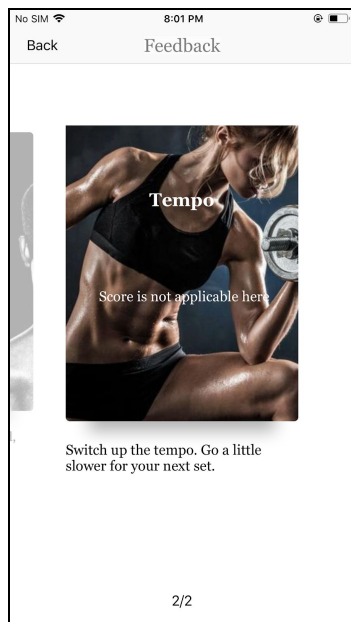
Progress

Users can review their performance history over time to track progress and identify trends. For example, if a user notices substantial negative accelerations they may be provoked to consult a trainer or therapist for correcting this asymmetry, before any serious injuries develop.
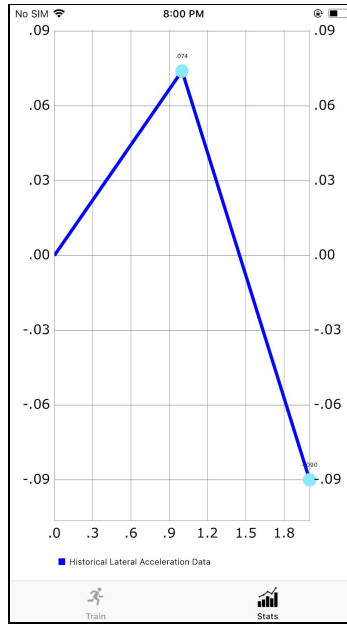
Overall Design

User Auth
A component to authenticate existing users and create accounts in Firebase for new users

User Input
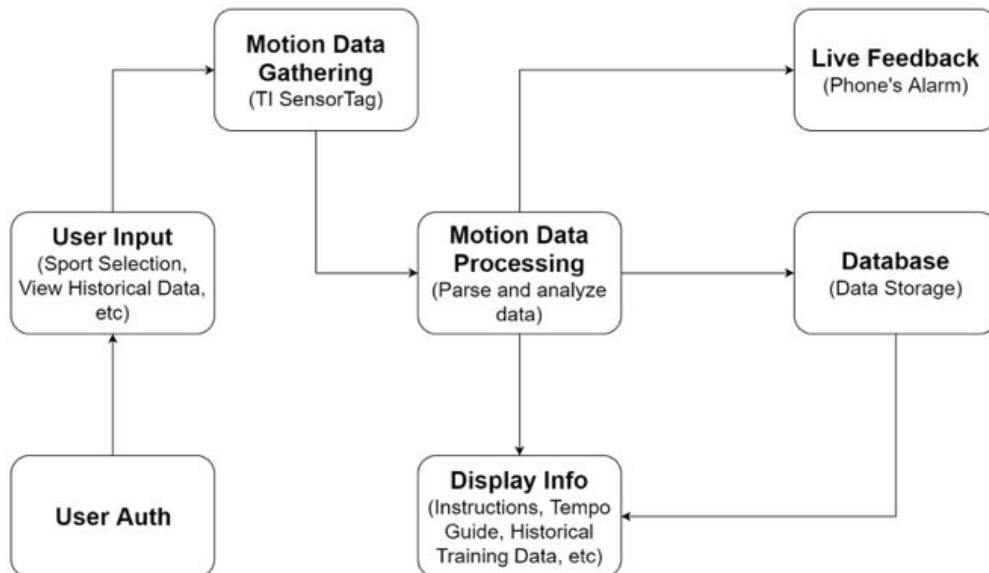A user interface component to collect input from users, such as activity selection and historical data

Motion Data Gathering
To read raw data from the SensorTag(s)

Motion Data Processing
To parse the raw data from the SensorTag(s) into more readable and usable forms

Live Feedback
To trigger the alerts from the smartphone based on predetermined data thresholds

Database
To store the data in Firestore for checking historical performance and progress

Display Info
To display information for the user to view; information will include historical performance data and activity instructions

Reflection

What we learned.

App development
We learned about iOS app development using Swift, as well as general mobile application principles that can be applied to other operating systems as well. It was a special experience to apply a specific scientific concept to technology that can be used by anyone.

UX/UI

We learned about UX/UI design and how to use free UI libraries. We became aware of the importance of user testing to ultimately refine the app to a version that was user-friendly.

Communication

Throughout this project, our communication as a group improved. We learned how to convey concepts from our own fields to those who may be less familiar. Using GitHub was a valuable experience, as it helped us organize projects and summarize our progress. In addition to communicating within our group, we learned how to communicate as a group to other audiences when presenting a product.

What we would do differently.

UX/UI

We found ourselves iterating through very different UX/UI versions throughout development, eventually completing an entire refactor in the last spiral. It would have been more effective to create a storyboard from the beginning and continued to add features to that.

Sensor

We would have investigated the TI SensorTag firmware more carefully in the first spiral. Technical difficulties delayed our progress in the early stages of development.

Data collection

We would have leveraged more types of data. Acceleration is very useful in the context of human movement. However, displacement and orientation data may have provided more comprehensive insights into asymmetries, which became a primary focus in our app.

Focused goal

TruMove was initially intended as an all-in-one training app for multiple sports and activities. However, it may have been more effective to develop it for more niche contexts. The app might be better to supplement trainers, not replace them. We would develop it again as a streamlined assessment tool for specific populations; for example, an assessment app for older adults who would like to jog more.

Contributions

Qingsong Meng contributed to the UX/UI design and backend's code implementation. For the UX/UI part, he helped design the overall user workflow and implemented UI components and backend logics for authentications, guidelines, and the live workout page. For the backend logics, he implemented code for the motion data gathering, motion data processing, database interactions, and real-time feedback. He thoroughly tested the application throughout development. He was also responsible for source code control on GitHub by constructing pull requests, managing active branches, and resolving conflicts in pull requests.

Zhixuan Wang contributed mainly to the UX/UI design, code implementation, and sketch of the backend. She first sketched all UX/UI components in pure code, then changed them all in the storyboard according to the design. In the following reiterations, she implemented different UI libraries. For example, she implemented the *Folding Cell* in the instructions page and the *Expanding Collection* in the summary page. She continually tested the UX/UI design throughout development. For the sketch of the backend, she implement the collected data and stored in Firebase functions. She also contributed to committing to the source code on GitHub.

Amir Boroomand-Tehrani contributed with his expertise in the movement sciences He wrote all of the training protocols, including: instructions, guidelines, and feedback. His expertise was instrumental in reporting kinematic data into performance metrics that were functional in the relevant context. He contributed to providing input on a user experience that would be best suited for users in a gym environment. He designed graphics that the programmers implemented into the app. He prepared all reports and presentation materials ahead of classes.

Specialist Context

TruMove can influence motor practice and learning in the context of research, training, and therapy.

Research
Kinematic data is useful for measuring performance outcomes that allow researchers to make inferences about motor control. However, it is often collected using large and expensive motion capture equipment. TruMove allows for kinematic data to be collected with technology that is widely accessible and relatively

inexpensive. It also allows for large samples of data to be collected in real-world scenarios that are more difficult to recreate in a laboratory setting. For example, TruMove could eventually be leveraged to collect kinematic data on individuals' regular activity, such as walking.

Training

Receiving feedback can accelerate motor skill development and learning, ultimately leading to enhanced performance. In competitive sports, athletes seek any advantage to better than their opponents. By providing performance metrics based on measurements that are otherwise unseen, athletes can have a greater advantage to guiding their training and learning motor skills more efficiently. With detailed instructions and guidelines for performing activities properly, novice athletes can also benefit from using TruMove. Having this information in the early stages of motor skill development can help establish fundamentals in technique that more advanced skills become easier to build upon. Real-time feedback in the form of alerts can partially replace the need for personal trainers who are often costly.

Therapy

Preventing injury became one of the primary goals of TruMove. Therapists could potentially use TruMove to record movement during assessments. Although slight asymmetries may not seem detrimental, they can slowly develop into more problematic misalignments if not corrected. Identifying these asymmetries early on can help guide corrective therapeutic strategies to prevent further exacerbation. TruMove may be particularly useful in telerehabilitation where therapists and clients communicate, usually via video-conferencing, from different locations. When operating remotely, it can be difficult for therapists to make accurate judgments on user movement. TruMove could provide therapists with objective movement data when they are not face-to-face with clients.

Future Work

Additional data

Collecting more types of kinematic data, such as displacements and angles, could provide more comprehensive insights on performance. This is a reasonable implementation as this data is readily collected from the TI SensorTag. The addition of multiple external sensors can also provide more insight on asymmetries and how multiple body parts interact. Using the front-facing camera sensor, TruMove could record video footage data of the user practicing an exercise. This video footage could then be overlaid with specific feedback, such as angles, that are easily understood by users.

Component learning
Sports often include complex movements with multiple stages of motion that are not necessarily linear or unidimensional. Segmenting movements into individual components could help users identify specific areas for improvement and provide feedback that is easier to understand.

Instructions
Videos or GIFs in the instructions pages may be useful for learning technique. This could be further enhanced by implementing augmented reality during live practice sessions. For example, a user can reach for virtual targets as they perform an exercise, ultimately guiding them through the proper technique.

History
Having the option to view history by different time periods, such as weekly and monthly, would create a cleaner UI for tracking progress. It would also help user identify slower improvements in performance.

Statements of Consent

I, Qingsong Meng, give full consent to publish the video of the final presentation, report, and source code on the course website.

I, Zhixuan Wang, give full consent to publish the video of the final presentation, report, and source code on the course website.

I, Amir Boromand-Tehrani, give full consent to publish the video of the final presentation, report, and source code on the course website.

References

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