Mines Field Session: SwingLens AI Video Training System

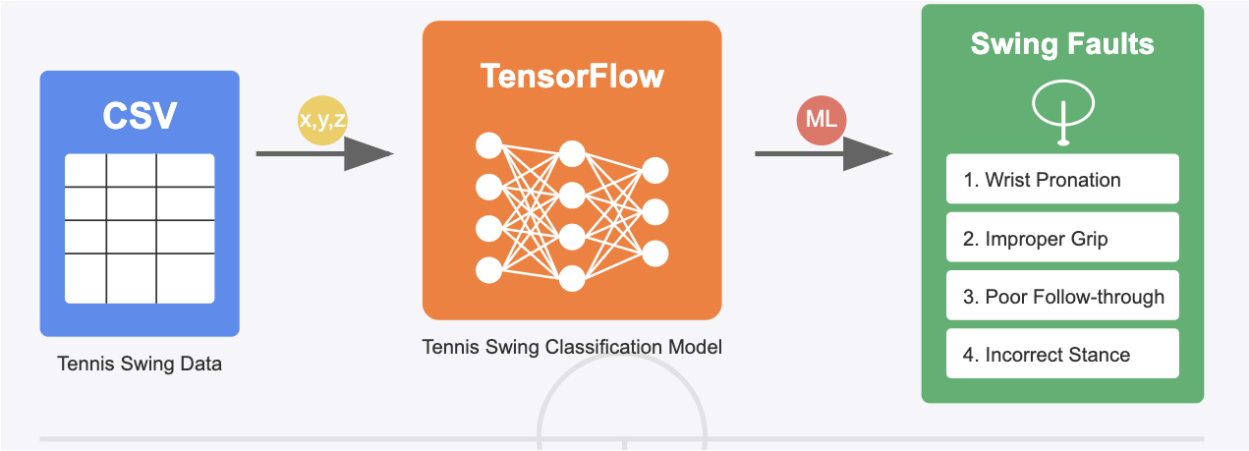
Summer 2025

Company Background

SwingLens is an early stage startup focused on automatic analysis of tennis swings using machine learning approaches. It strives to make tennis more accessible to the masses by allowing athletes to improve their tennis swing using a simple mobile app. The company advisor is Peter Laird, an architect at Salesforce.

Project Description

This project is one aspect of the full solution. This project is focused on building a data pipeline that trains ML models to identify swing faults of tennis athletes by analyzing data obtained from digital cameras. The data contains the x,y position of 17 human body parts (right elbow, left wrist, left eye, etc) in each frame of each video. The data is available as CSV files.



Each swing fault has indicators in the data which can be detected by ML. Certain body parts contain more indicators of each swing fault. In some cases, multiple swing faults will be present in a single swing. The goal of the system is to score a swing based on the probability of each detectable swing fault.

A solution has been demonstrated in a limited prototype. The goal of this project is to explore the pipeline deeply, and to find the optimal architecture of the ML models. It will determine the limits of the approaches and recommend the best solution.

Key considerations:

- In the prototype, a simple convolutional network architecture (CNN) was used for detection. Iterate on this and determine the best approach.

    - The positional data for a body part was plotted over time (each frame of the video) as an image
    - The image was classified using an example image classification CNN provided by TensorFlow.
- Should each body part (right elbow, etc) be analyzed individually, or should the data from multiple body parts be aggregated in some way?
    - Additionally, in the prototype, it was observed that certain swing faults can show some evidence in just a single positional dimension (x or y) in a single body part.
- Should there be a trained model for each detectable swing fault, or will a single trained model for all faults work sufficiently?
- There are many permutations of a tennis swing, how should the ML system be designed to accommodate this?
    - Should there be a trained model for each swing type (forehand top-spin, backhand slice, forehand swing volley, etc), or will a single trained model for all swing types work sufficiently?
    - Similar considerations for variations in footwork, ball height at impact, player ability level, player age, etc.
- Ultimately, the training data will contain data from up to 8 different camera angles. The live system when in use will obtain data from only one camera. It is planned for the live system to select the best set of models that were trained using the most relevant camera angle, but is there a better way?

Project Details

The primary goal of this project is to determine the most accurate way to detect swing faults in a tennis swing. It is expected that the primary strategy will be to use ML to classify the fault, but it is likely that the best approach will combine several strategies. Also, for each implemented pipeline, there will likely be many different permutations of parameters that can be varied to test for optimum results.

The project will have the following outputs:

- Data pipelines written in Python. It is expected that they will use Tensorflow, but other packages may be used as well.
- Each pipeline will run in two modes - training and test.
- A final report that explains the different approaches that were tested, and the recommended solutions.

Key practices that should be followed:

- Source code organization and management will be key. As you iterate through the experiments, make sure to keep copies of exactly what code was used and the parameters used for each run.
- It is likely that the best solution will involve multiple steps, of which ML is only one.
- If a pipeline is multiple steps, use CSV files in between each step to keep them separate and individually testable/composable.

    - Bringing in a framework like PySpark would be possible in a future iteration, but is probably overkill at this time unless the team is already experienced in it.

It is helpful to see the results of the prototype that was built last year: Stella Laird science fair project. Note that this field session is furthering the ML approaches of the prototype, not the numerical approaches.

If the initial goals are met, the team may continue to work to make this system more product ready. The other SwingLens field session team will be building a database with swing metadata and CSV data in AWS. The system developed in this field session ultimately needs to connect to that data repository. If time allows, this field session will implement this connectivity.

Logistics

- This is a team project for up to four students.
- We will meet virtually multiple times per week to discuss progress, and in-person based on availability.
    - For some of the session, the project sponsor will be traveling abroad and will only be available remotely.
- SwingLens may have paid internships available after the Field Session completes.

This field session is one of two for SwingLens this summer. The first field session is building the video capture system that will ultimately produce the data used to train the models in this second field session. This creates a sequencing problem, as this project will not have a complete set of data to work from at the start. Instead, this project team will have a limited data set produced for the prototype. This data set contains 24 swings of each category (model swing, each swing fault), a single swing type, with a single camera angle.

As the project progresses, the other field session team may be able to provide a more complete data set for use in the training of the models in this field session. It will be helpful to keep in contact with the other team to get more data as it becomes available.

Intellectual Property

Students will not be required to sign an NDA. Students will be able to showcase their work in future job applications. However, all intellectual property shall be retained by SwingLens LLC.