

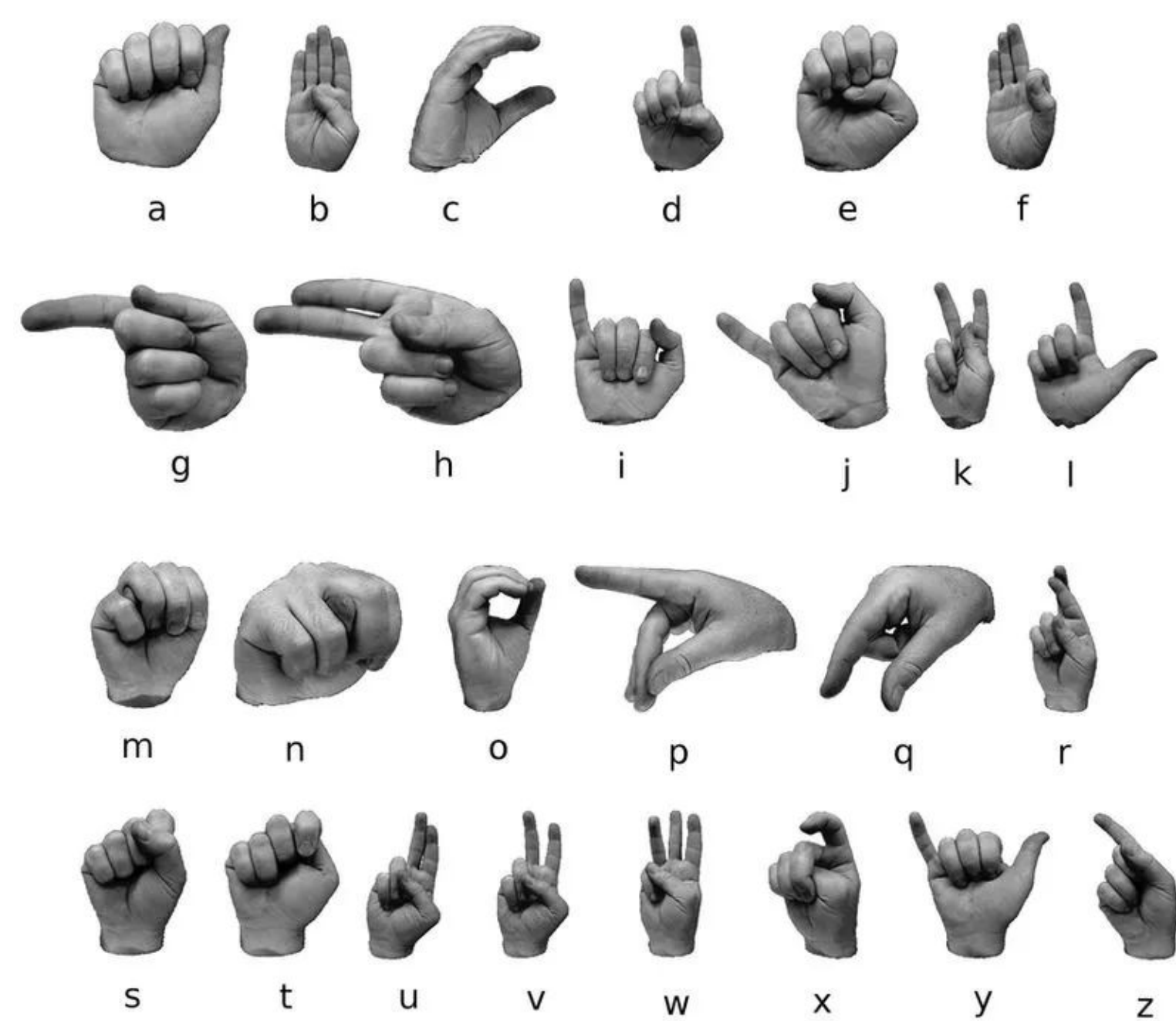
## Executive Summary

**SignQuest** is an interactive learning ecosystem that transforms a standard webcam into a personal sign language tutor, gamifying the learning experience. By integrating real-time computer vision with generative AI, the platform moves beyond static video to provide a personalized feedback loop for ASL learners.



## Background

- Learning American Sign Language can be challenging without real-time feedback or access to instructors
- Many existing tools lack interactive features to help users correct their signing in the moment
- There is a need for an engaging, technology-driven platform that makes ASL learning more accessible and personalized



Hand Signs

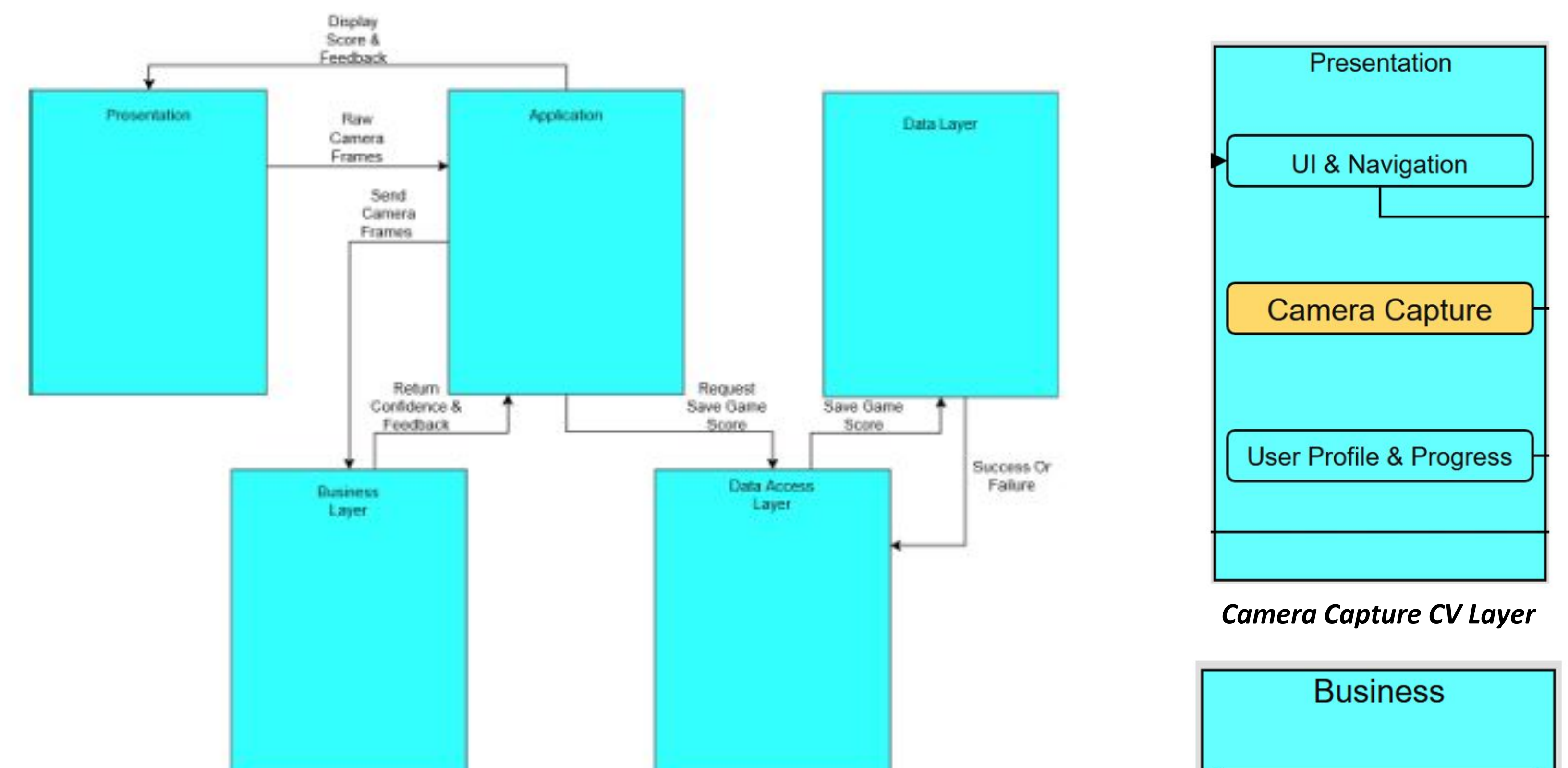
## Experimental Setup and Project Architecture

**Hardware Environment:** Client devices equipped with standard webcams for real-time capture, utilizing CPU/GPU processing for low-latency model inference.

**Core Software Stack:** Python 3.10+, OpenCV, MediaPipe, TensorFlow/PyTorch, and FastAPI.

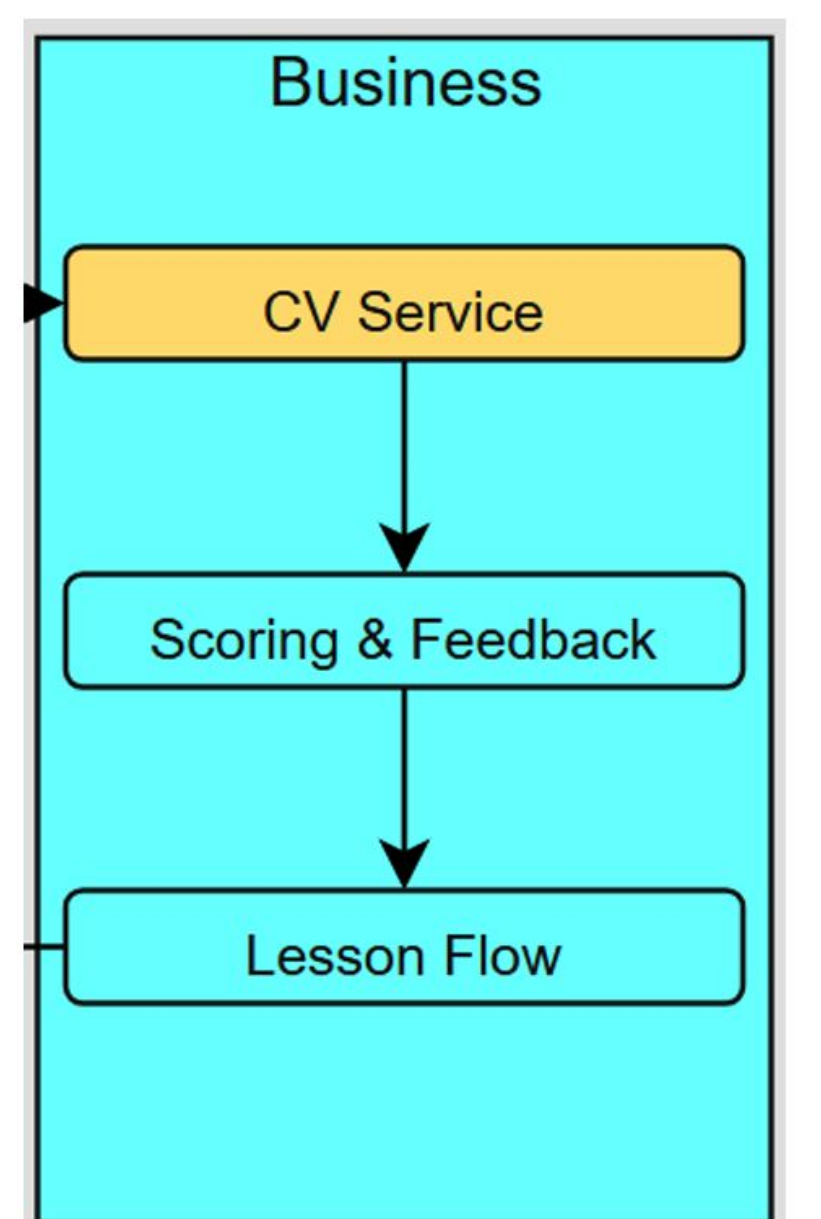
**Computer Vision Pipeline:** Real-time frames are captured and processed via MediaPipe to extract 21 3D hand landmarks.

- Landmarks are normalized and passed into a trained TensorFlow/PyTorch classification model.
- A custom Low-Latency Prediction Debouncer applies a sliding window "majority vote" to smooth out frame-by-frame jitter.



SignQuest architectural layer diagram

Camera Capture CV Layer



Scoring and Feedback Engine diagram

**LLM Feedback Loop:** Incorrect predictions and landmark coordinates are formatted and sent to the Google Gemini API, which generates natural-language corrective feedback for the user

## Experimental Test Plan

- We trained the computer vision model to maintain over 85% classification accuracy across the ASL alphabet.
- We stress tested the Prediction Debouncer to minimize latency and stabilize live video inference.
- We verified the entire data pipeline and confirmed that database sharding scales reliably under high user loads.

## Experimental Results

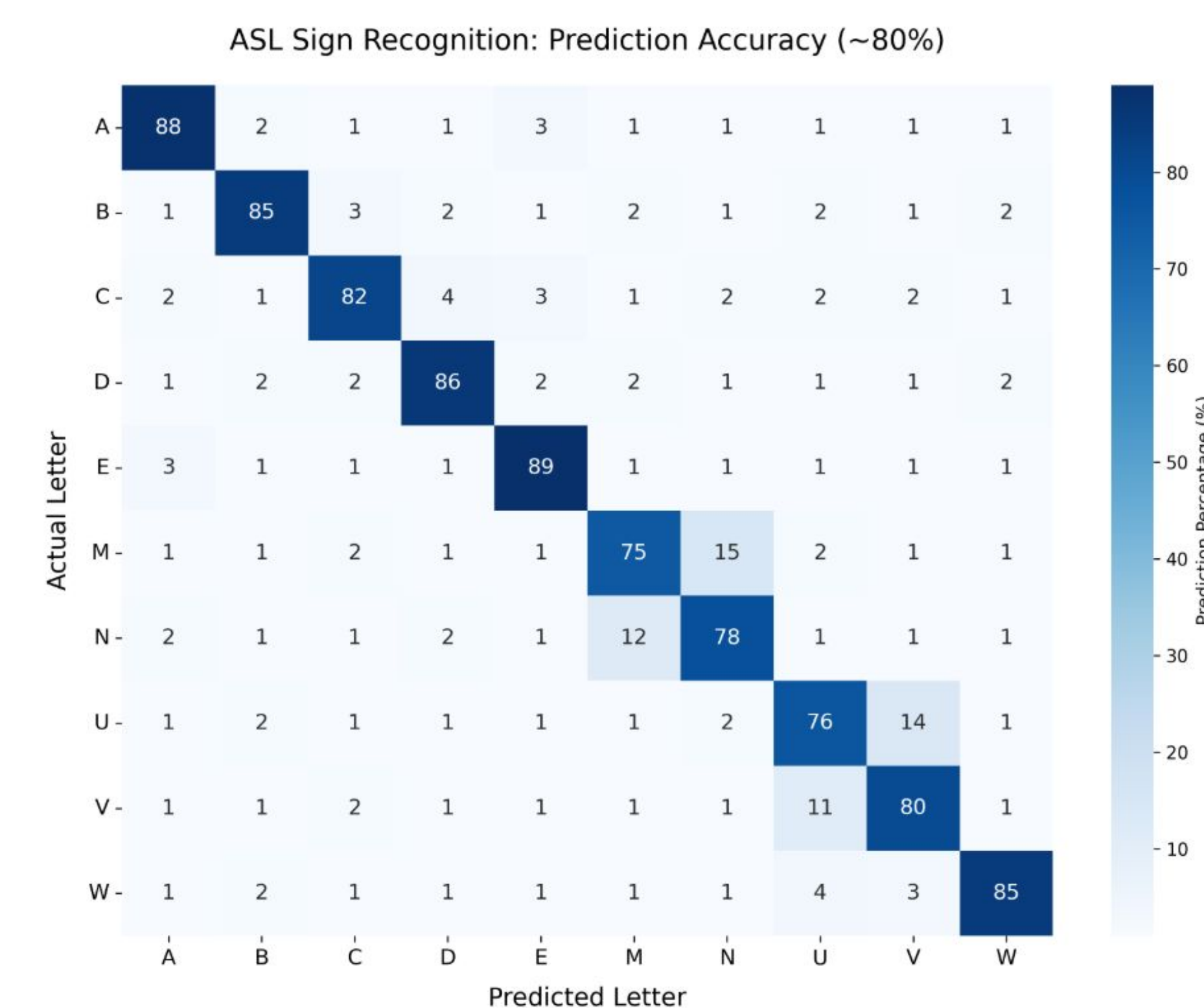
- Model inference achieved a 15ms average response time for real-time feedback.
- Overall classification accuracy reached approximately 80% across the ASL alphabet.
- Misclassifications were primarily isolated to visually similar sign pairs like M and N or U and V.

## Conclusions

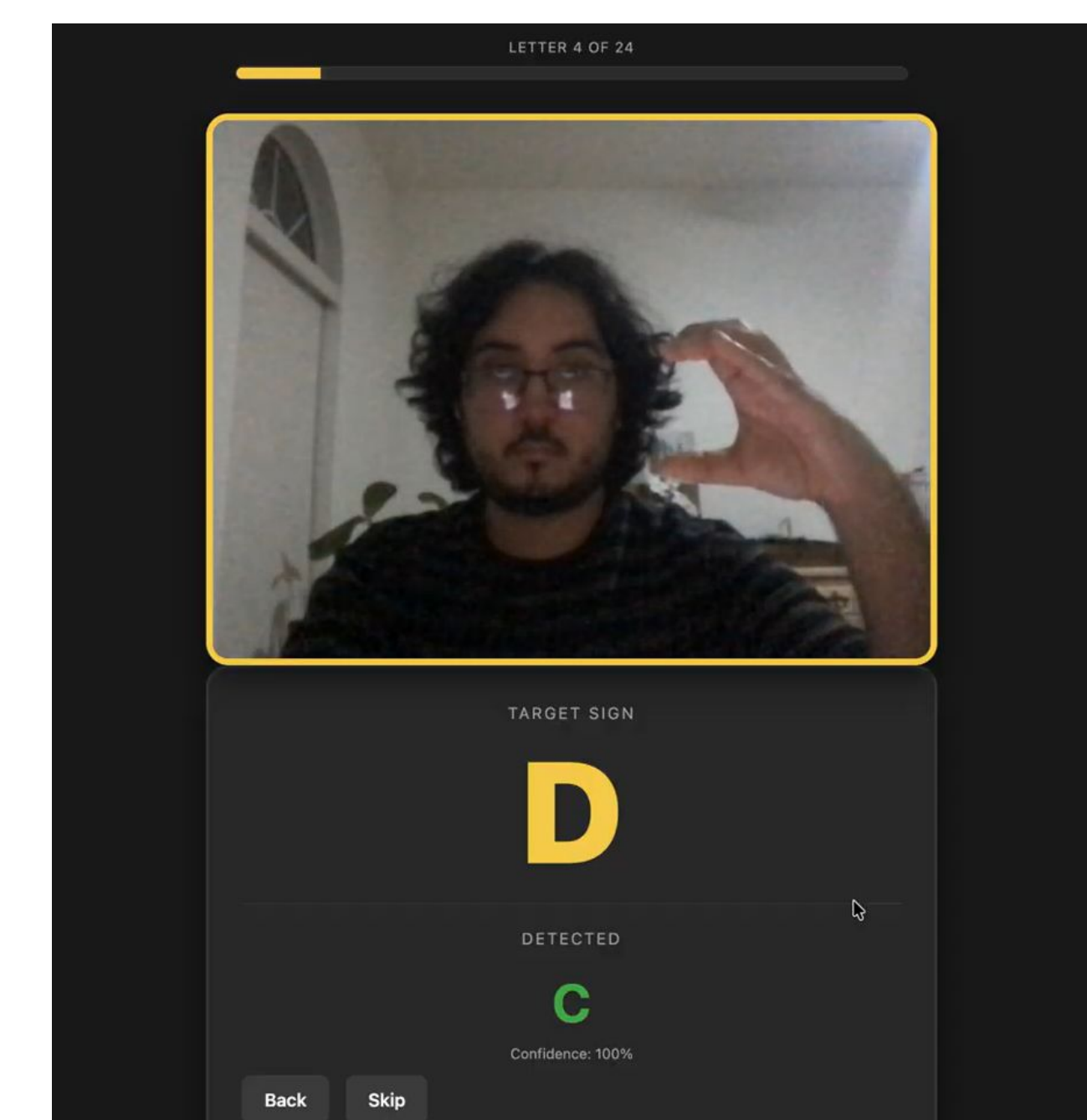
- SignQuest currently has been tested to work in a well lit environment with all letters in the alphabet which meets our goals for this MVP.
- Future plans include going beyond letters and signing words and sentences, developing additional mini games, developing competitive modes, and making the application work in a variety of situations.

## References

- Liu, S., and Bobrow, J. E., "An Analysis of a Pneumatic Servo System and Its Application to a Computer-Controlled Robot," *ASME Journal of Dynamic Systems, Measurement, and Control*, 1988, Vol 110 pp 228-235.



Results Confusion Matrix



Subject holds up "C" sign instead of D, model accurately predicts "C"