Segmentation and Key Frame Extraction for Analyzing Educational Research Videos

Group: DKHTNI

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"**D**ucks **K**eep **H**unting **T**iny **N**ymphs **I**ntently."
"**D**atabases **K**eep **H**uge **T**ables **N**eatly **I**ndexed."

Project Background

The Need for Video Analysis Tools in Educational Research

- Educational Psychology Research
- Video Analysis
- Students' gestures as answering math problems
- No tools automatically support for this

Task: Identify specific type of gestures

- **Examples: *Representational gesture, (Non-)Dynamic gesture, etc.***
- **Highly abstract concepts in educational psychology**

Problem Statement

Developing an Intermediate Layer to Bridge Low-Level Data with High-Level Analytical Needs

High-level Needs (Identification of *Abstract Gesture Type*)

Intermediate Layer (Construction of *Gesture Chunk*) **Our Project**

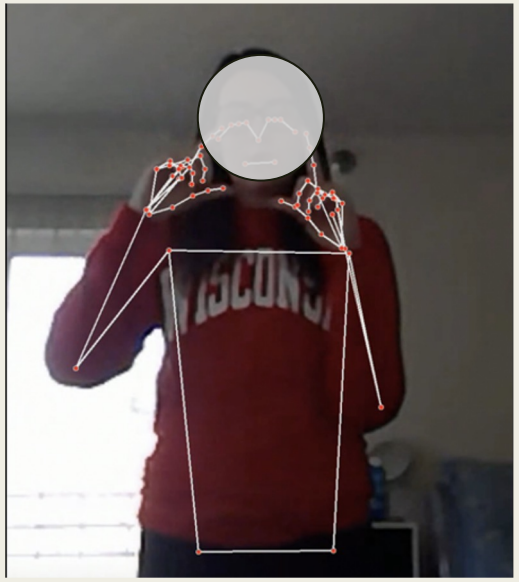
Low-level Data (Coordinates of *Body/Hands Landmarks*)

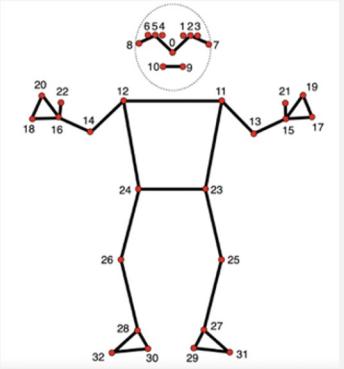
Data set

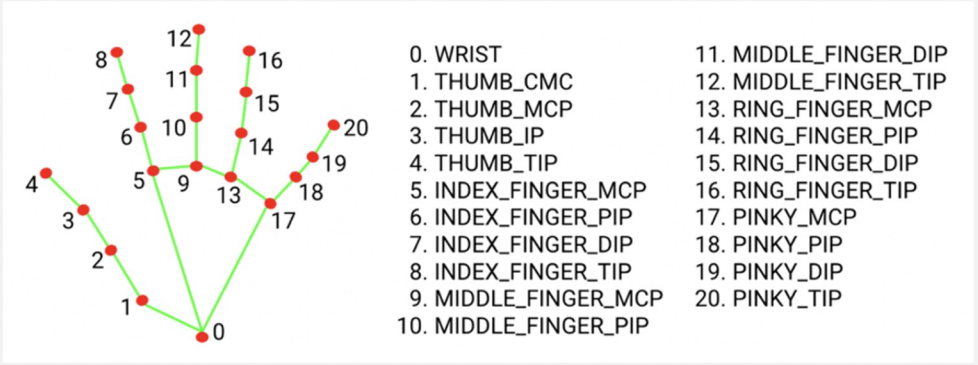
- 127 Video files (102 GB)
- Research in Embodied Geometry
- Magic Lab
- Department of Edu Psych

Tools

- OpenCV
- Mediapipe
- Stick figure model







Low Level Data: Coordinates of Body/Hands Landmarks

High-Level Needs

```
# Unit of analysis
# Carrier of gesture-related features
struct Gesture Chunk {
    # Identify 'idle' and
    # 'active' sections
    segmentation: TODO

    # Recognition hand gesture
    # for each hand in each frame
    simple_hand_gestures: TODO

    # Extract keyframes to summarize
    # current chunk
    keyframes: TODO
}
```

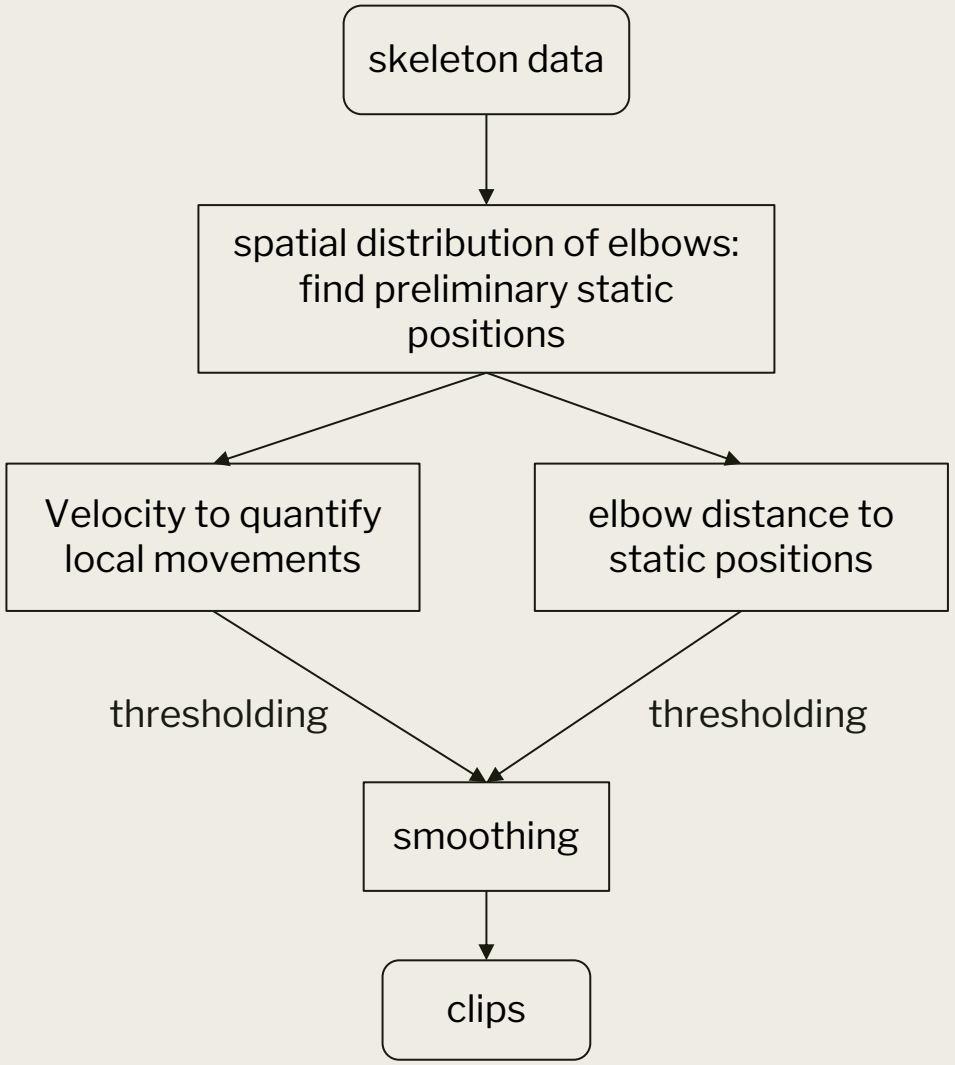
Low-Level Data

Intermediate Layer: Construction of Gesture Chunk

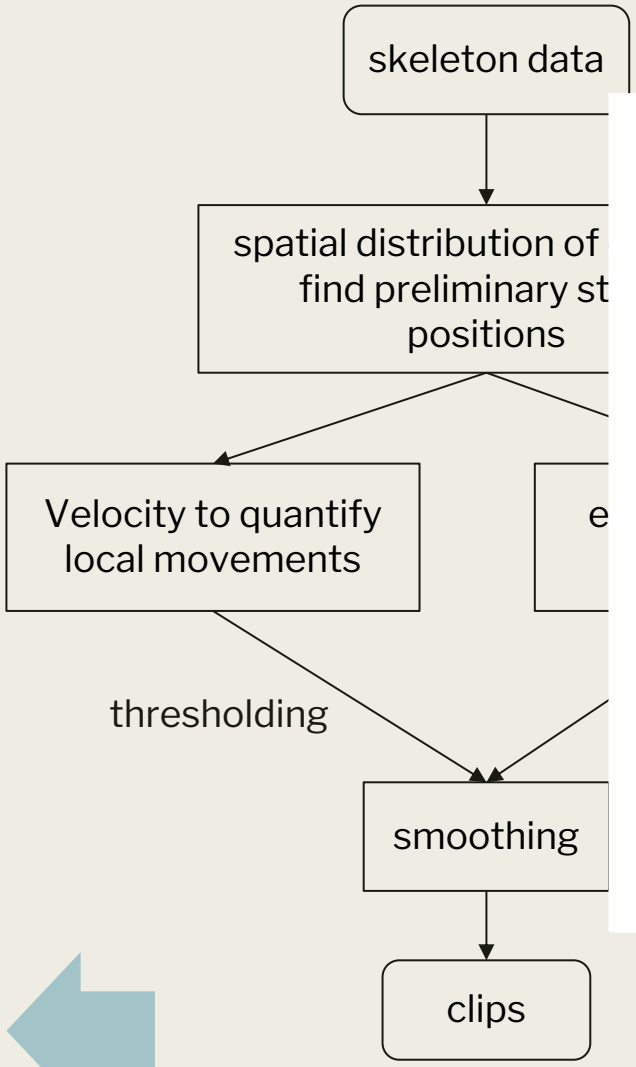
Temporal Segmentation: Existing Algorithms

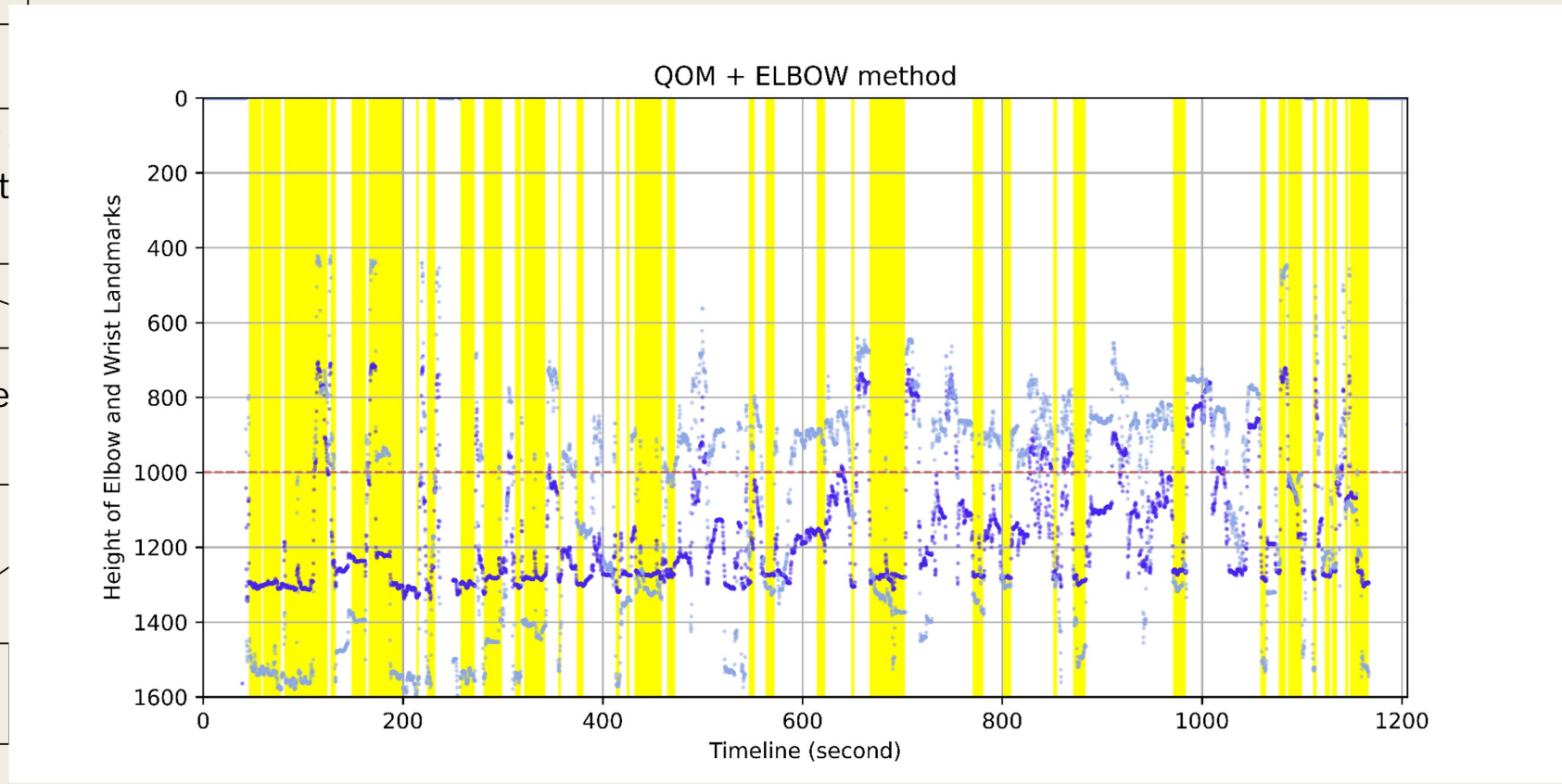
Papers	Key concepts
[1] Jiang, Feng, et al. "Multi-layered gesture recognition with Kinect." *J. Mach. Learn. Res.* 16.1 (2015): 227-254.	Quantity of Movement + thresholding
[2] Peng, Xiaojiang, et al. "Action and gesture temporal spotting with super vector representation." *European Conference on Computer Vision*. Cham: Springer International Publishing, 2014.	Spatial distribution of hand positions + distance of current hand position to static position
[3] Madeo, Renata CB, Clodoaldo AM Lima, and Sarajane M. Peres. "Gesture unit segmentation using support vector machines: segmenting gestures from rest positions." *Proceedings of the 28th Annual ACM Symposium on Applied Computing*. 2013.	Velocity and acceleration as feature vector + support vector machine classification

Temporal Segmentation: Our Algorithms



Temporal Segmentation: Our Algorithms





Simple Hand-Gesture Detection

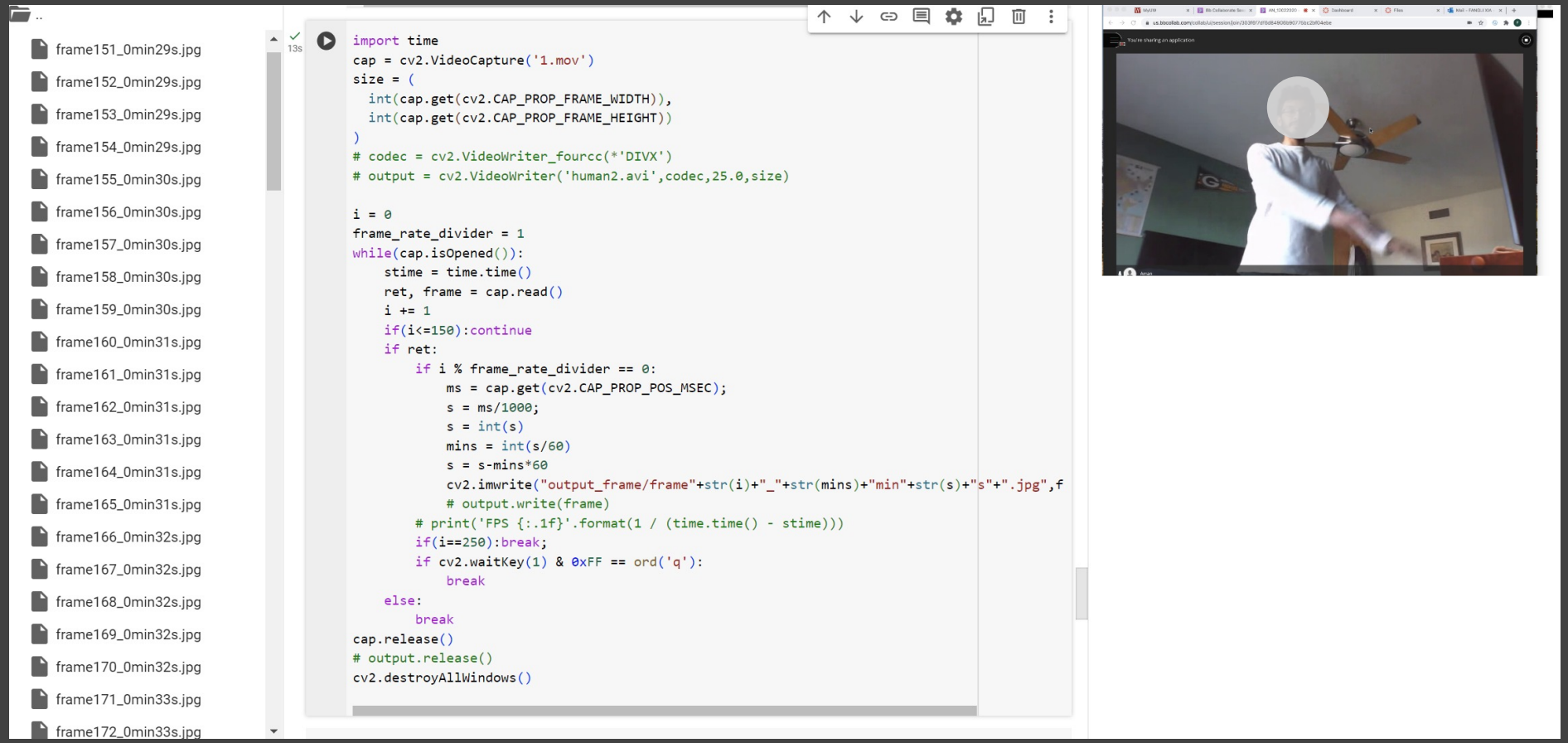
One important feature of active gesture chunk: Gesture of Hand
8 distinct categories:

- Palm
- Fist
- Thumb Up
- Indexing
- L-shape
- Relax
- Other
- Missing

} Other

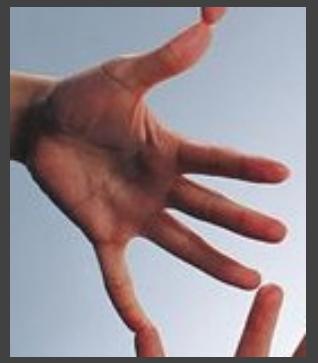
Method:

1) Extract Frame



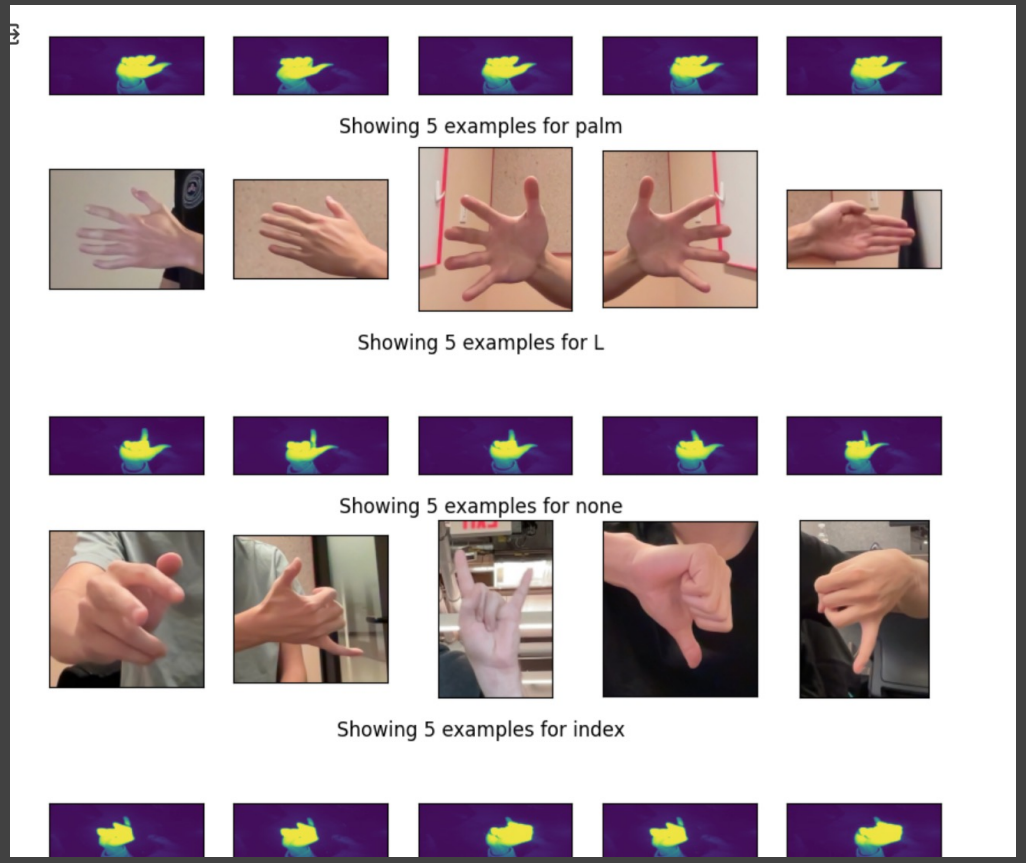
Simple Hand-Gesture Detection

2) Crop Out Hand using MediaPipe



Simple Hand-Gesture Detection

3) Train Gesture Classification and apply: 80% for train 10% for val, and 10 for test



Simple Hand-Gesture Detection

3) Train Gesture Classification and apply

```
# Train the model
hparams = gesture_recognizer.HParams(export_dir="rock_paper_scissors_model", batch_size =8,
    epochs=20,)
options = gesture_recognizer.GestureRecognizerOptions(hparams=hparams)
model = gesture_recognizer.GestureRecognizer.create(
    train_data=train_data,
    validation_data=validation_data,
    options=options
)
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 hand_embedding (InputLayer  [(None, 128)]             0
 )

 batch_normalization (Batch  (None, 128)               512
 Normalization)

 re_lu (ReLU)                (None, 128)               0

 dropout (Dropout)           (None, 128)               0

 custom_gesture_recognizer_  (None, 4)                 516
 out (Dense)

=================================================================
Total params: 1028 (4.02 KB)
Trainable params: 772 (3.02 KB)
Non-trainable params: 256 (1.00 KB)
_________________________________________________________________
None
Epoch 1/20
47/47 [==============================] - 4s 52ms/step - loss: 1.2161 - categorical_accuracy: 0.2420 - val_loss: 0.7115 - val_categorical_accuracy: 0.5
Epoch 2/20
47/47 [==============================] - 1s 16ms/step - loss: 0.6147 - categorical_accuracy: 0.5452 - val_loss: 0.3462 - val_categorical_accuracy: 0.7
Epoch 3/20
47/47 [==============================] - 1s 16ms/step - loss: 0.4304 - categorical_accuracy: 0.6941 - val_loss: 0.2212 - val_categorical_accuracy: 0.8
Epoch 4/20
47/47 [==============================] - 1s 16ms/step - loss: 0.3449 - categorical_accuracy: 0.7420 - val_loss: 0.1632 - val_categorical_accuracy: 0.9
Epoch 5/20
47/47 [==============================] - 1s 16ms/step - loss: 0.2725 - categorical_accuracy: 0.7872 - val_loss: 0.1332 - val_categorical_accuracy: 0.9
```

Simple Hand-Gesture Detection

3) Train Gesture Classification and apply

```
[ ]  loss, acc = model.evaluate(test_data, batch_size=1)
     print(f"Test loss:{loss}, Test accuracy:{acc}")
```

```
48/48 [==============================] - 1s 2ms/step - loss: 0.0857 - categorical_accuracy: 0.9375
Test loss:0.08573845773935318, Test accuracy:0.9375
```

Simple Hand-Gesture Detection

To simplify our project, we aim to recognize hand gestures in eight distinct categories:

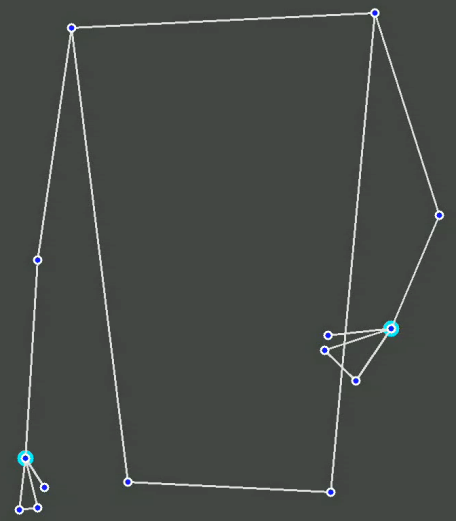
- **Palm**
- **Fist**
- **Thumb Up**: extending the thumb
- **Indexing**: extending the index finger
- **L-shape**: extending both the thumb and index finger to form an L-shape
- **Relax**: the hand in a relaxed state
- **Other**: any other hand positions
- **Missing**: insufficient hand landmarks detected for classification

Keyframe Extraction

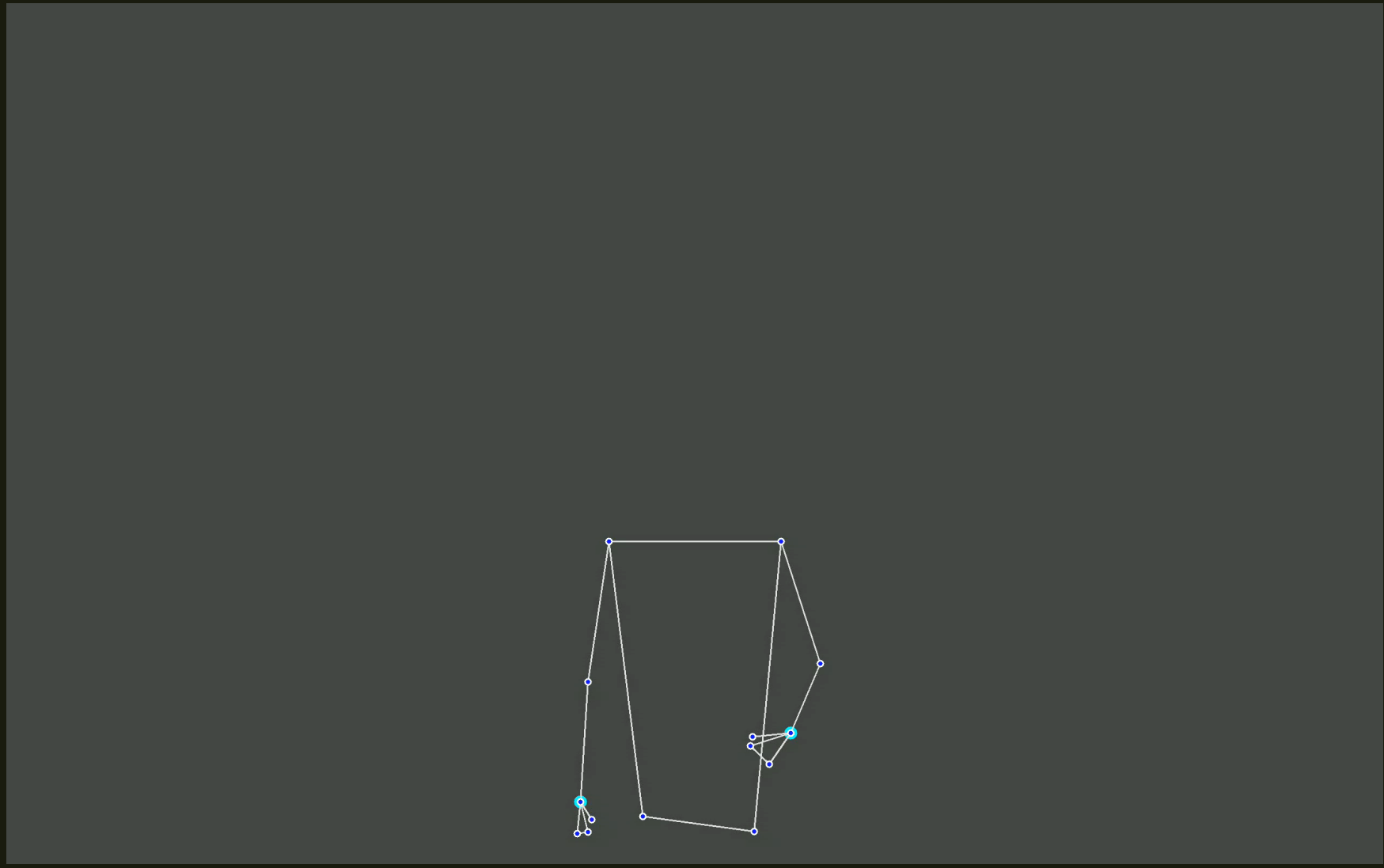
- **Purpose**
  - Use less frames to represent a gesture chunk
- **Algorithm**
  - (Wrists) Velocity and position-based filtering
- **Example Results**
  - Scenario: a student explaining whether “the lengths of the two diagonals of a rectangle are the same”
  - Duration: 30 sec
  - Original Frames: **129**
  - Extracted frames: **15**

Video from 129 Original Frames

Question: “Are the lengths of the two diagonals of a rectangle the same?”



Video from 15 Extracted Keyframes



Challenges

- **Label**: Abstract nature of targeted gestures
- **Noise**: Presence of various noise types
- **Feature**: Absence of an intermediate feature construction layer
- **Data**: Limited dataset size post-'idle' state removal and inaccuracies in landmark detection by MediaPipe

Future Directions

- Enhance baseline algorithms for better feature extraction
- Strengthen algorithm robustness by incorporating edge cases
- Integrate keyframe extraction with hand gesture recognition
- Construct models using gesture chunks for simple gesture identification
- Advance the model to recognize more abstract gestures

Thank You!

From Group

“Dreams Kindle Hope,
Transforming New Ideas.”