Deep Learning-based Pose Estimation for Dystonia Score Prediction

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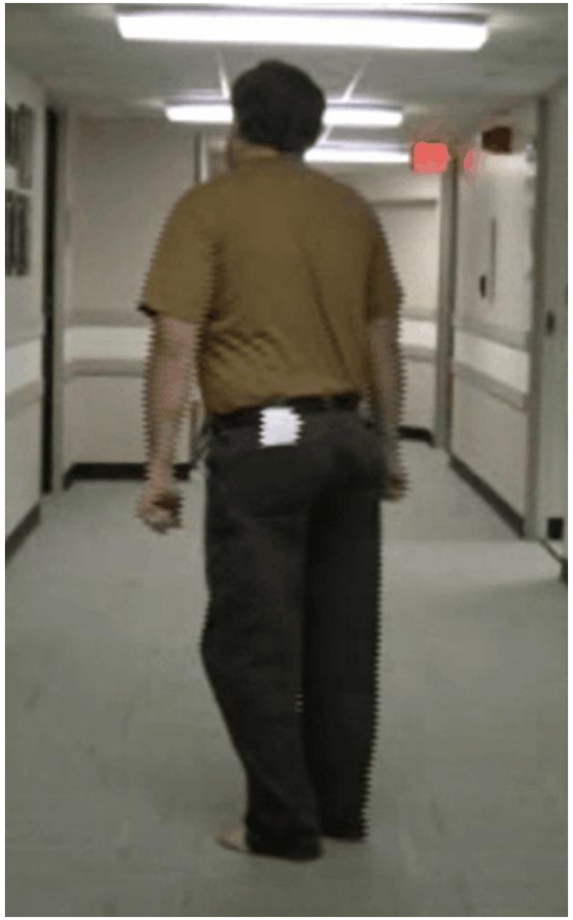
Presentation Outline

Problem Definition

- **Dystonia**: a neurological movement disorder
  - repetitive/twisting movements or muscle contractions
  - cause not known yet; no cure
  - medications/ surgery can improve symptoms
- **Personalized** selection of medicines and doses
  - need frequent clinic visits
  - expert medical personnel to measure symptoms
- Subjective bias
  - need **objective assessment**



Motivation

- Revolution in automation/ intelligent systems
- Resource-constrained environment: remote Nepal
  - telemedicine: assess dystonia patients in remote area
  - supplement frequent clinic visits
- Accelerating clinical trials with objective assessment
- Eyewitness of complexities with neurological disorder

Objectives

Are **computer vision-based** approaches capable of an **automated non-obtrusive clinical assessment** of dystonia?

- Assess feasibility of current computer vision method
- ML model to probe the presence of dystonia
- Explore possible features for the ML models

Scope of Project

- Generic dystonia:
  - specific dystonia requires complex modelling
- Can’t cope with falsification of medical situation
- Used open-source pose estimation algorithm
- 2D video capture method

Originality of Project

- **Firsthand processing** of very raw videos for pose analysis
  - Dystonia Coalition
- **Feasibility with pose-based model** for dystonia scoring model
- Original implementation of **dystonia scoring model** with CNN

Project Applications

- Telemedicine: remote Nepal
- Regular assessments at home environment
  - results can be sent to their consulting neurologist
  - Supplement regular clinic visits
- Inspiration for other pose-based applications

Literature Review [1]

- Objective Assessment of Parkinson’s Disease Using ML

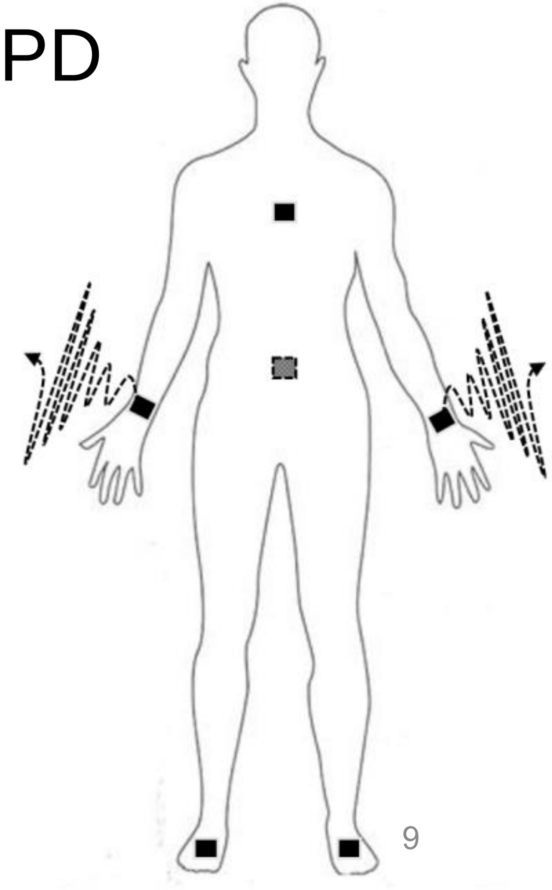
[Prince, 2018]

- Sensors to objectively and **quantitatively** evaluate PD

- **Wearable sensors** can aid in regular clinical care

  - but obtrusive; need technical expertise/devices

- Dataset deconstruction technique for **missing data**



Literature Review [2]

- Objective Vision-based Assessment of Parkinson’s Disease

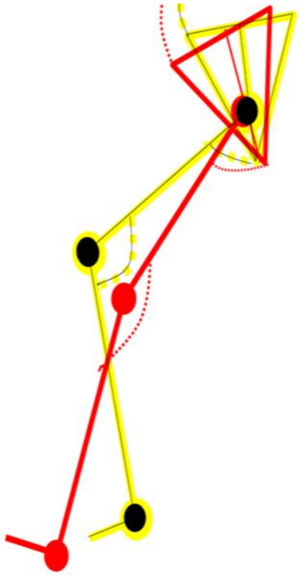
  [Li, 2017]

  - created Benchmark for the PD evaluation
  - evaluated two pose estimation methods : IDPR and CPM
  - **marker less** computer-based visual system/ Kinect 3D

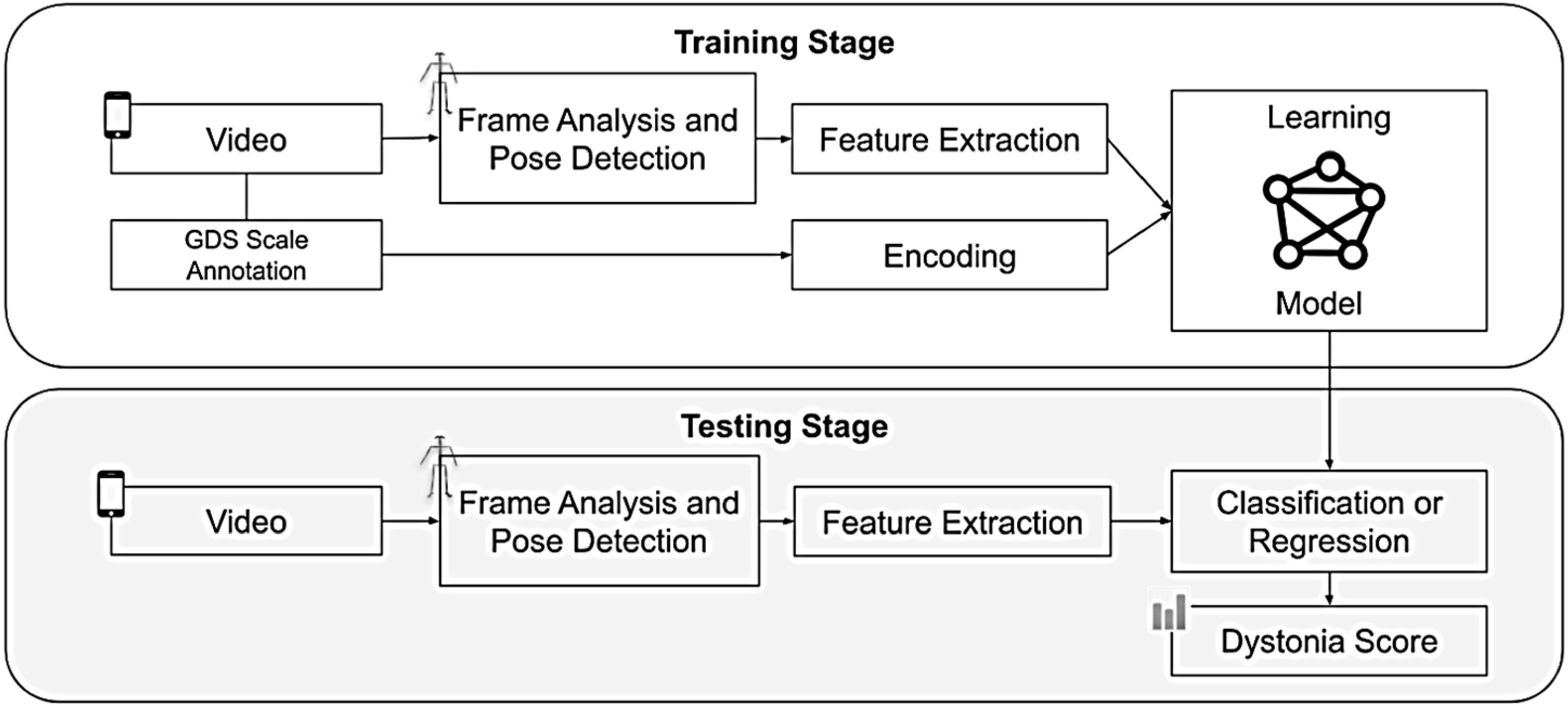
- **Automatic solution** to the need of frequent assessment
- Detect the presence of PD/LID and **severities**

Literature Review [3]

- Quantitative Movement Analysis Using **Single-Camera Videos** *[Kidzinski, 2021]*
  - derived **time series parameter** that improved model performance
  - **OpenPose** for extracting time series of human body landmarks
  - correlated predictions with real **clinical assessment values**
- **Multiple ML models** were trained for gait parameters.
- Model **generalizes** well to a diverse impaired population
- No need of **hand-crafted features**



Methodology: Overview



Methodology: Pose Estimation

OpenPose-COCO

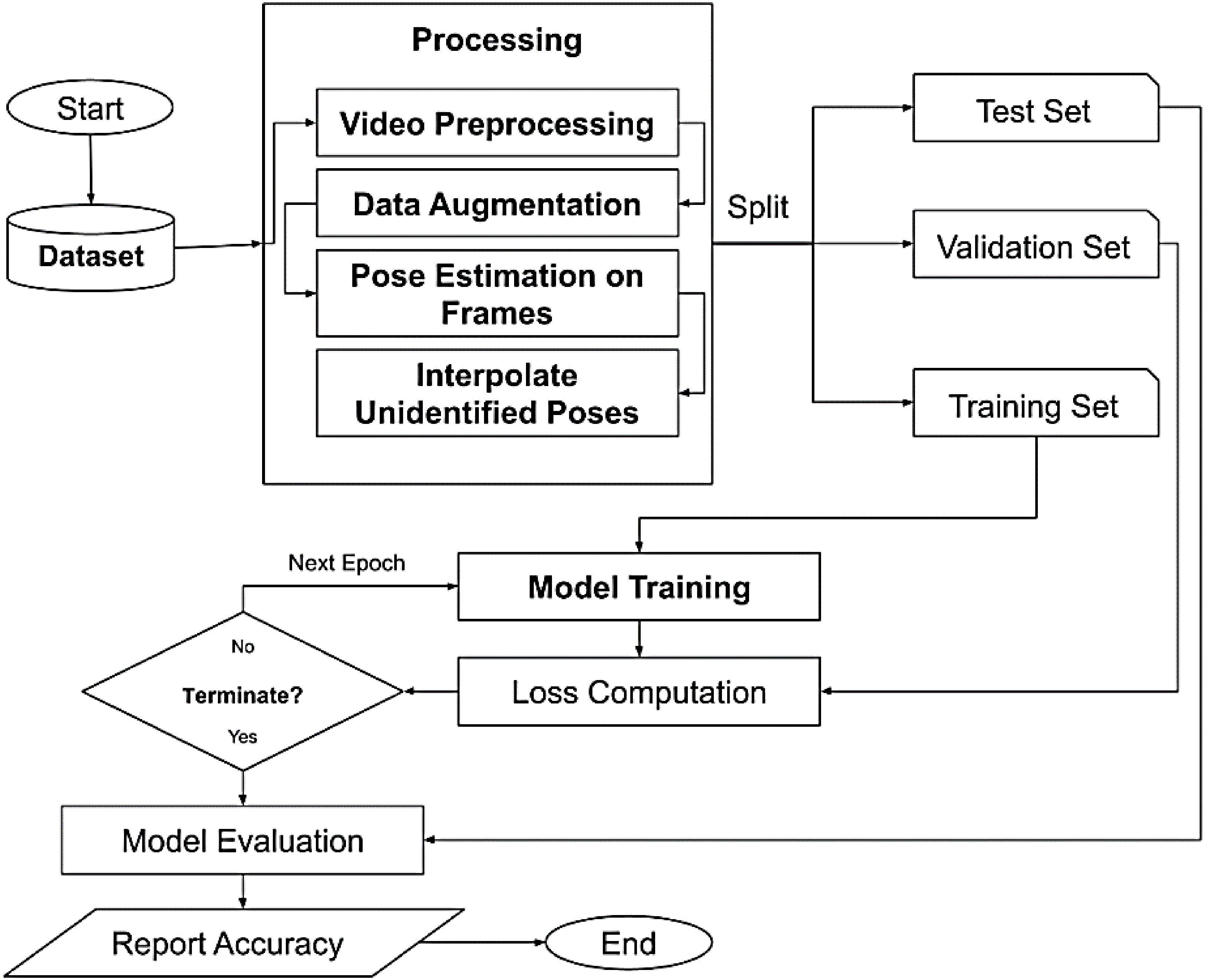
OpenPose-Body-25

Proposed Methodology:

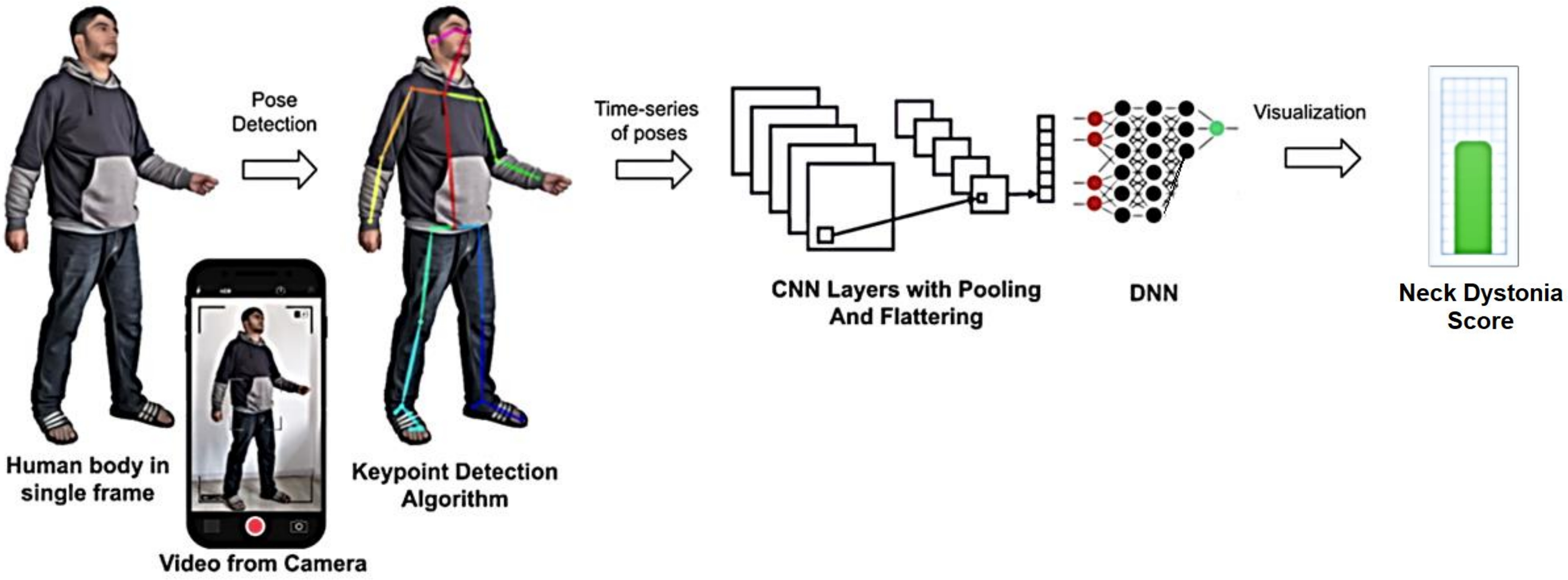
Global Dystonia Severity Rating Scale (GDS)

S.n.	Body Area	Ratings										Global Score
1	Eyes and upper face	1	2	3	4	5	6	7	8	9	10	
2	Lower face	1	2	3	4	5	6	7	8	9	10	
3	Jaw and Tongue	1	2	3	4	5	6	7	8	9	10	
4	Larynx	1	2	3	4	5	6	7	8	9	10	
5	Neck	1	2	3	4	5	6	7	8	9	10	
6	Shoulder and proximal arm (Right)	1	2	3	4	5	6	7	8	9	10	
	Shoulder and proximal arm (Left)	1	2	3	4	5	6	7	8	9	10	
7	Distal arm and hand including elbow (Right)	1	2	3	4	5	6	7	8	9	10	
	Distal arm and hand including elbow (Left)	1	2	3	4	5	6	7	8	9	10	
8	Pelvis and proximal leg (Right)	1	2	3	4	5	6	7	8	9	10	
	Pelvis and proximal leg (Left)	1	2	3	4	5	6	7	8	9	10	
9	Distal leg and foot including knee (Right)	1	2	3	4	5	6	7	8	9	10	
	Distal leg and foot including knee (Left)	1	2	3	4	5	6	7	8	9	10	
10	Trunk	1	2	3	4	5	6	7	8	9	10	
											Total Score	

Methodology: Training Flowchart



Methodology: Testing



Results: Interface [1]

Dystonia Data Viz All Data Profiling

Data List

Show 10 entries

Search:

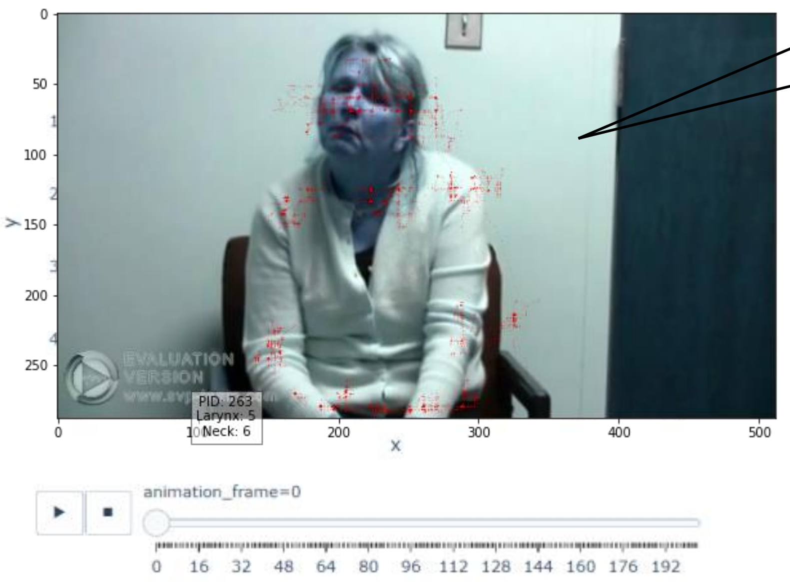
	SIZE_MB	HEIGHT	WIDTH	FPS	FRAME_COUNT	duration	PID	Visit Date	Gender	Age in years	Handedness	Type of Dystonia	Subtype	Size	Eyes and Upper Face
0	128.894308	360.0	640.0	29.969962	20654.0	689.156690	9	2011-01-27	Female	65.0	Right	Focal Dystonia	CranialDystonia Oromandibular	360x640	0
1	141.401143	480.0	640.0	29.969966	18609.0	620.921622	31	2011-04-15	Male	54.0	Right	Focal Dystonia	CranialDystonia Oromandibular	480x640	0
2	137.194061	480.0	640.0	29.970046	18951.0	632.331367	36	2017-05-10	Female	68.0	Right	Focal Dystonia	CervicalDystonia	480x640	0
3	195.645384	480.0	640.0	29.970035	25755.0	859.358367	41	2017-04-12	Female	81.0	Right	Focal Dystonia	CervicalDystonia	480x640	0
4	178.596715	480.0	640.0	29.963655	23525.0	785.117833	46	2016-06-29	Female	75.0	Right	Focal Dystonia	CervicalDystonia	480x640	0
5	164.763632	480.0	640.0	29.970016	21701.0	724.090367	48	2012-08-08	Male	59.0	Left	Focal Dystonia	CervicalDystonia	480x640	0
6	195.757988	360.0	640.0	29.969982	25770.0	859.860367	49	2015-10-22	Female	56.0	Left	Focal Dystonia	CervicalDystonia	360x640	0
7	154.069766	360.0	640.0	29.969999	20292.0	677.077100	57	2017-02-08	Female	76.0	Right	Focal Dystonia	CervicalDystonia	360x640	0
8	178.470975	360.0	640.0	29.966667	28273.0	943.481648	59	2011-05-11	Female	70.0	Left	Focal Dystonia	CervicalDystonia	360x640	0
9	153.940586	360.0	640.0	29.969999	20279.0	676.643333	62	2017-12-13	Female	77.0	Right	Focal Dystonia	CervicalDystonia	360x640	0

Results: Visualization [2]

Dystonia Data Viz All Data Profiling

Dystonia Visualization

OpenPose
Skip-100
Poses



Previous(I) | Save(O) | Next(P)

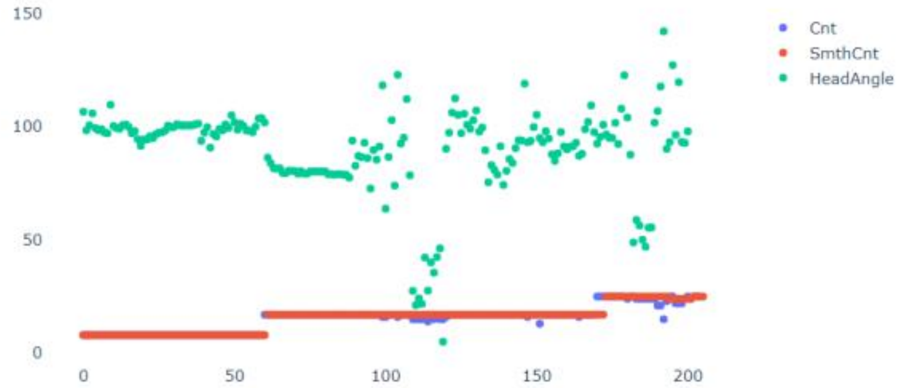
Play(Z), Pause(X) |

100 Start(N)

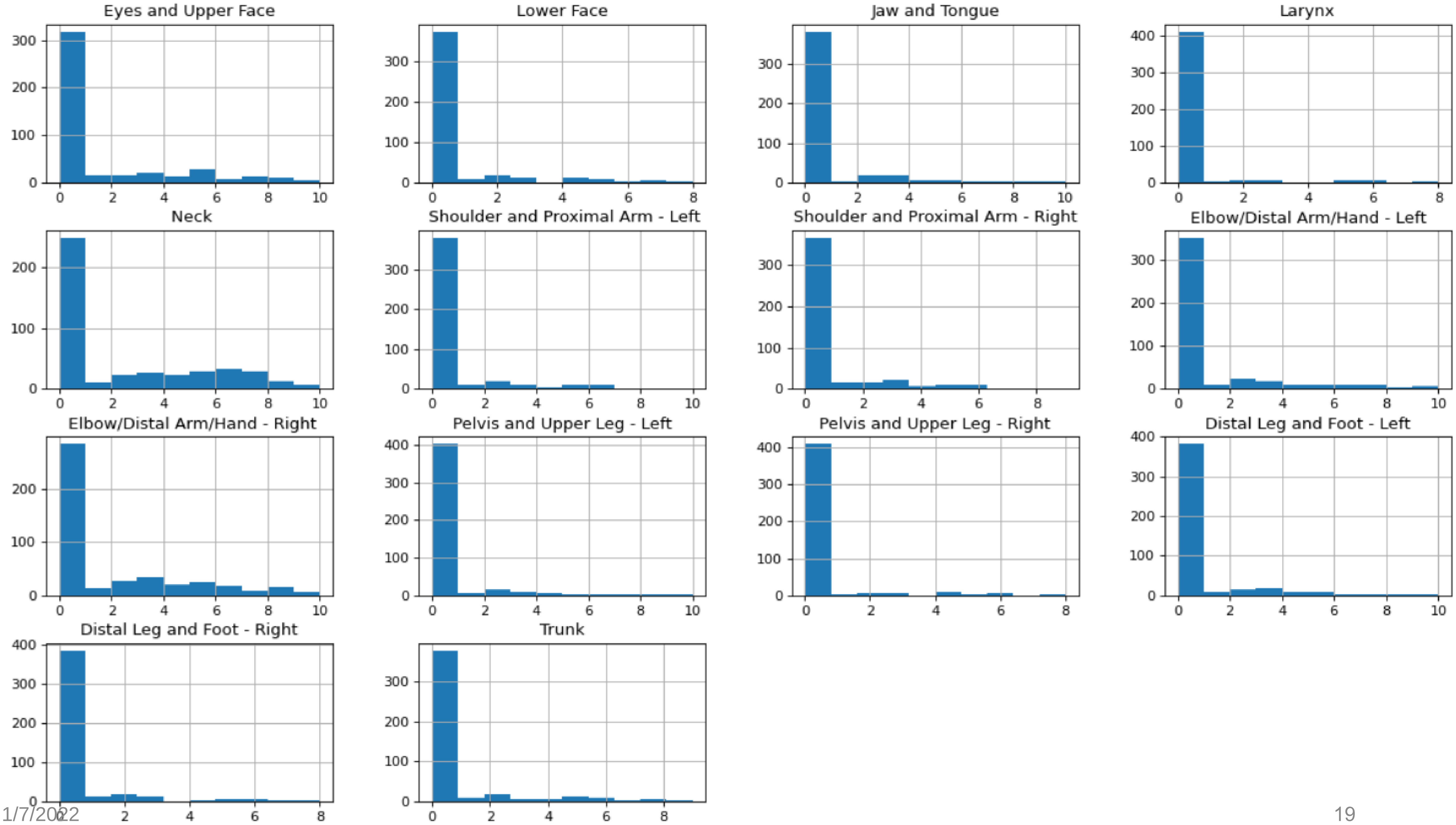
108 End(M)

50

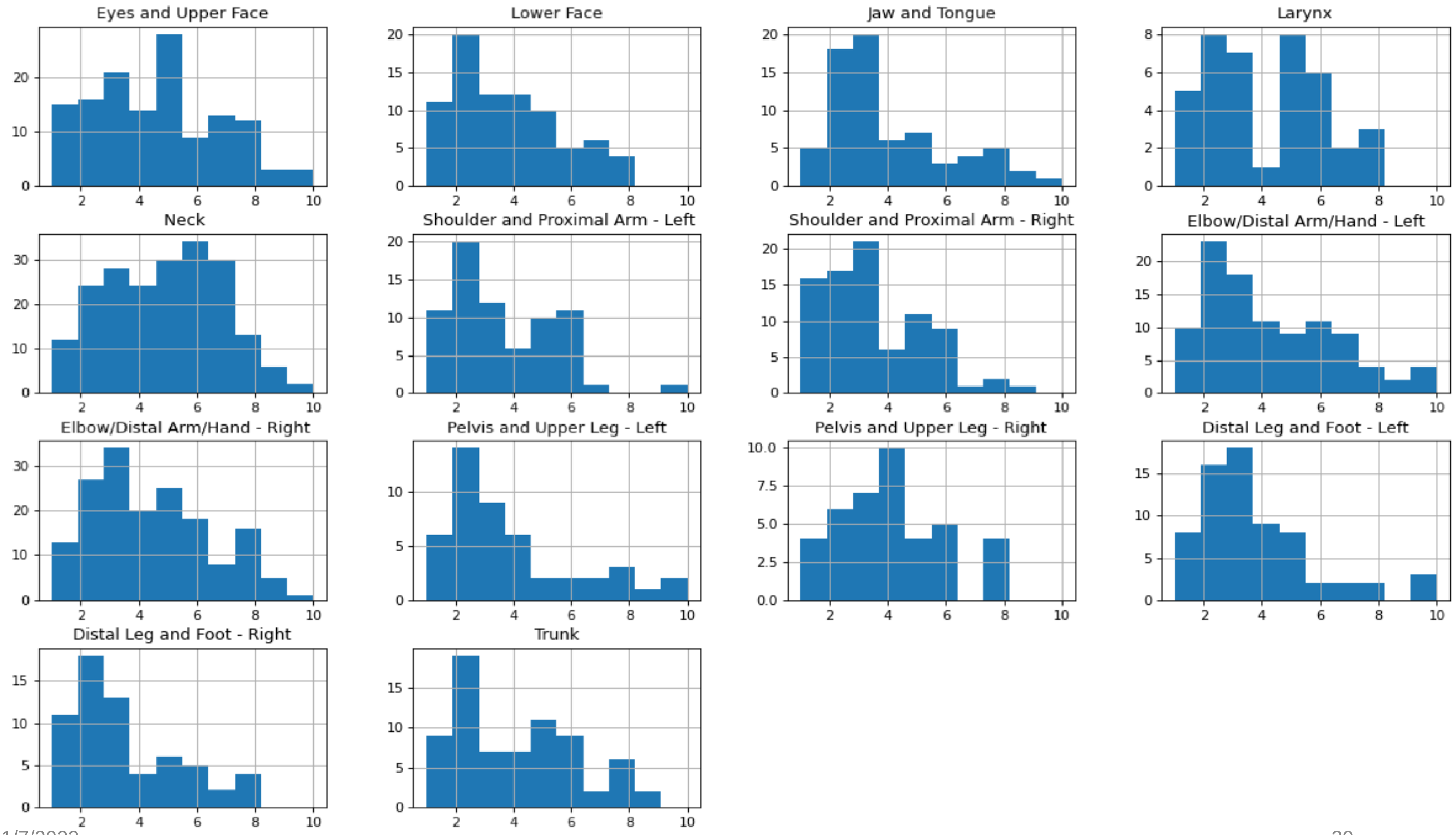
NAME	DYS674_20120712.mp4
SIZE_MB	155.348752
HEIGHT	360.0
WIDTH	640.0
FPS	29.969992
FRAME_COUNT	20445.0
duration	682.182367
PID	674
Visit Date	2012-07-12
Gender	Female
Age in years	60.0
Handedness	Right
Type of Dystonia	Focal Dystonia
Subtype	CervicalDystonia
Size	360x640
Eyes and Upper Face	0
Lower Face	0
Jaw and Tongue	0
Larynx	0
Neck	4
Shoulder and Proximal Arm - Left	0.0
Shoulder and Proximal Arm - Right	0.0
Elbow/Distal Arm/Hand - Left	0.0
Elbow/Distal Arm/Hand - Right	0.0
Pelvis and Upper Leg - Left	0.0
Pelvis and Upper Leg - Right	0.0
Distal Leg and Foot - Left	0.0
Distal Leg and Foot - Right	0.0
Trunk	0.0



Results [3]: Score Distribution

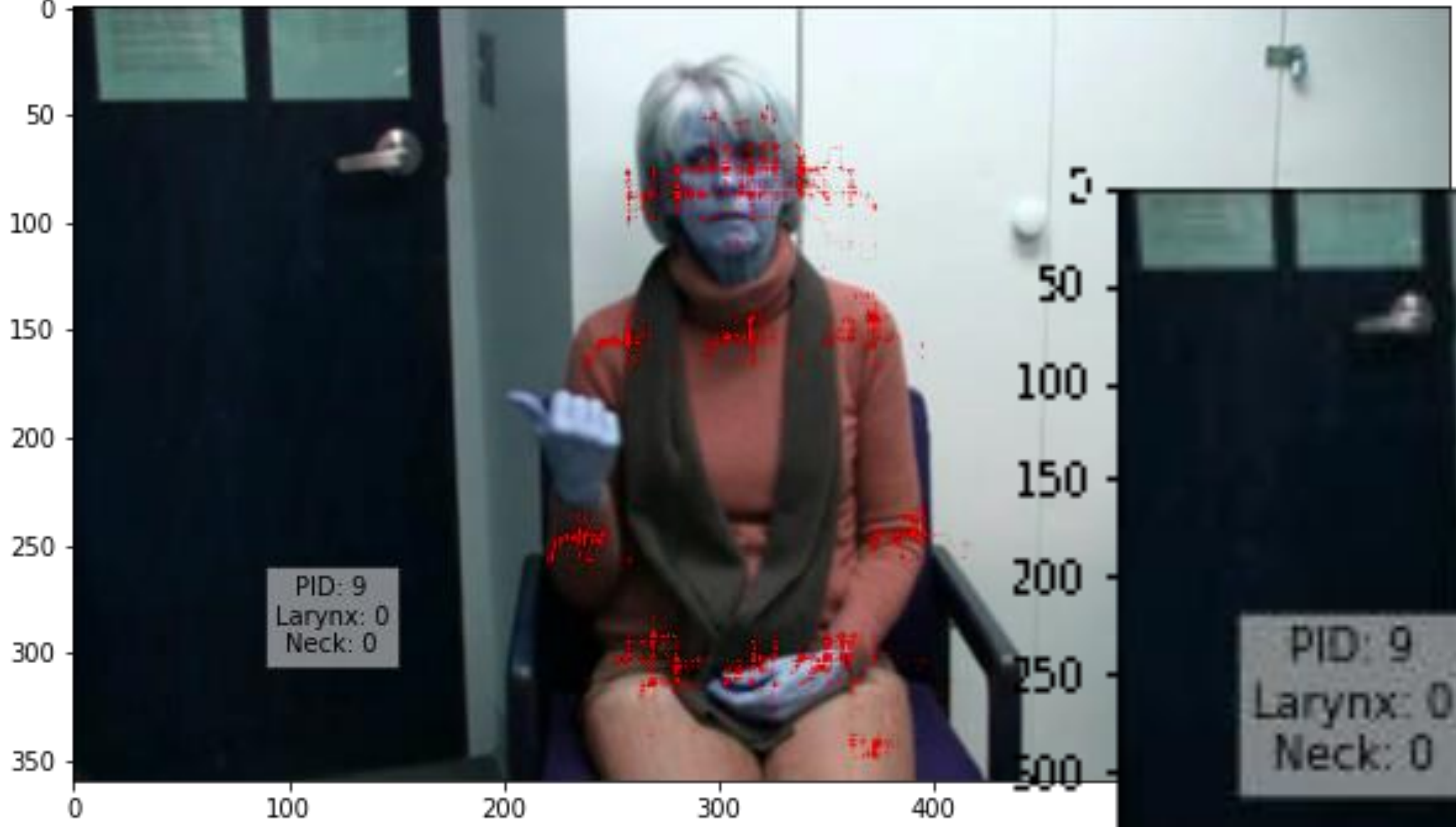


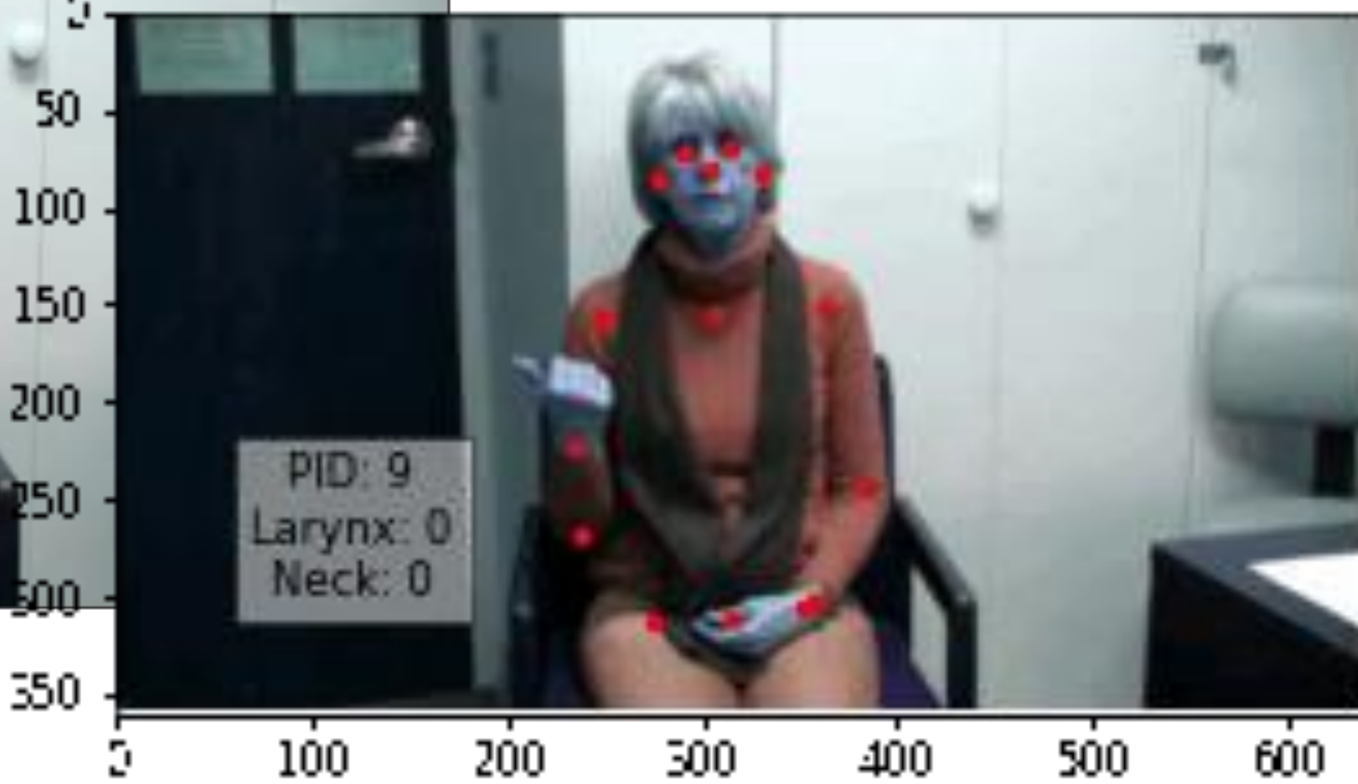
Results [4]: Score Distribution



Results: Score Distribution . . .

Results [5]: KP Visualization

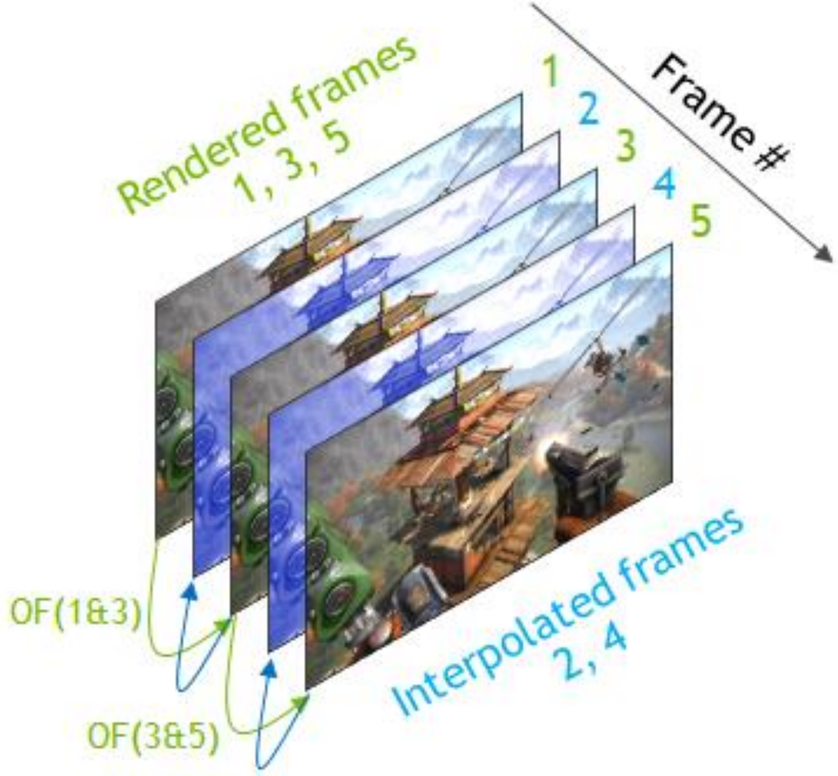




- Selection video segment type
- Manual Annotation
- Applying OpenPose on Segment

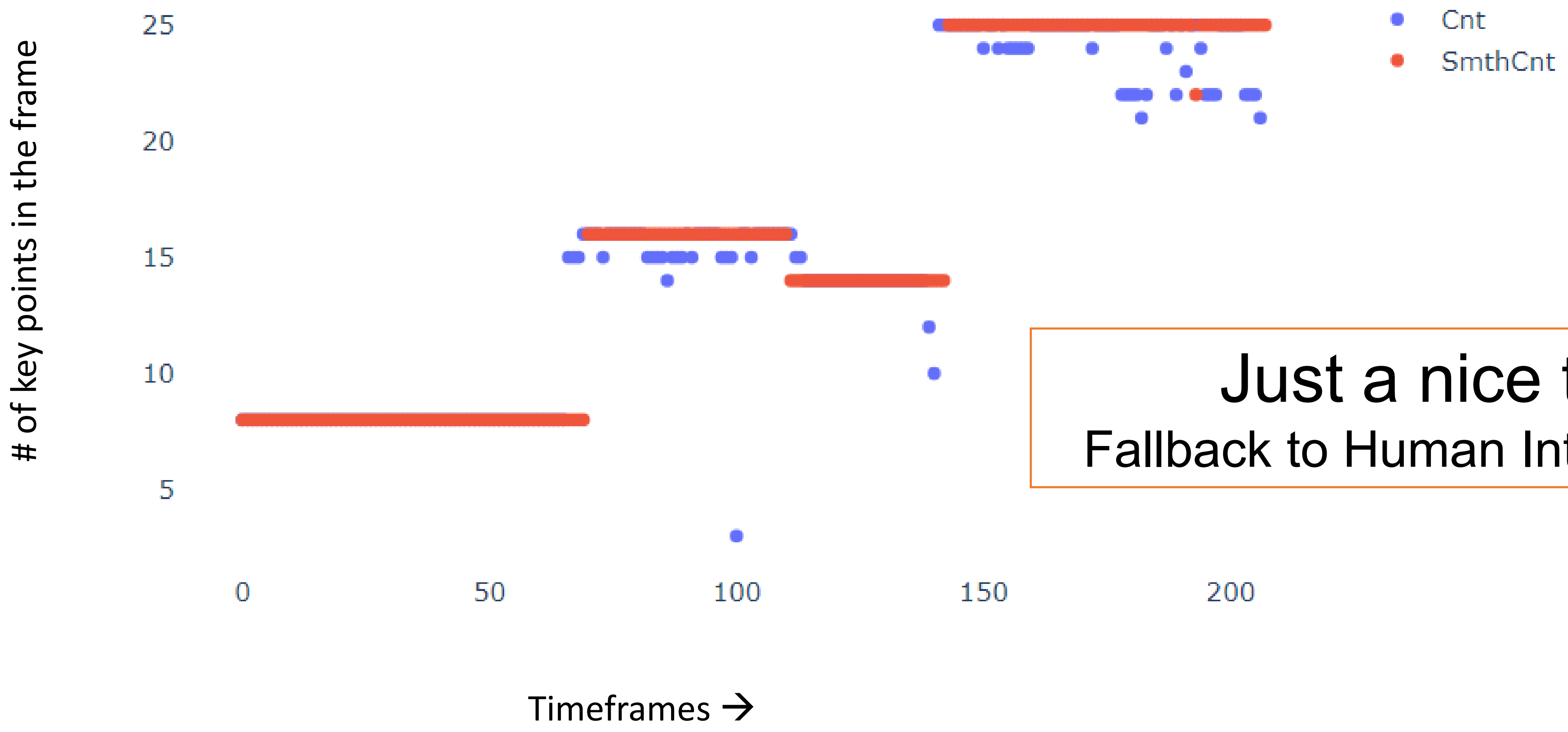
Results [6]: FPS Normalization

* Representative figure to indicate optical flow



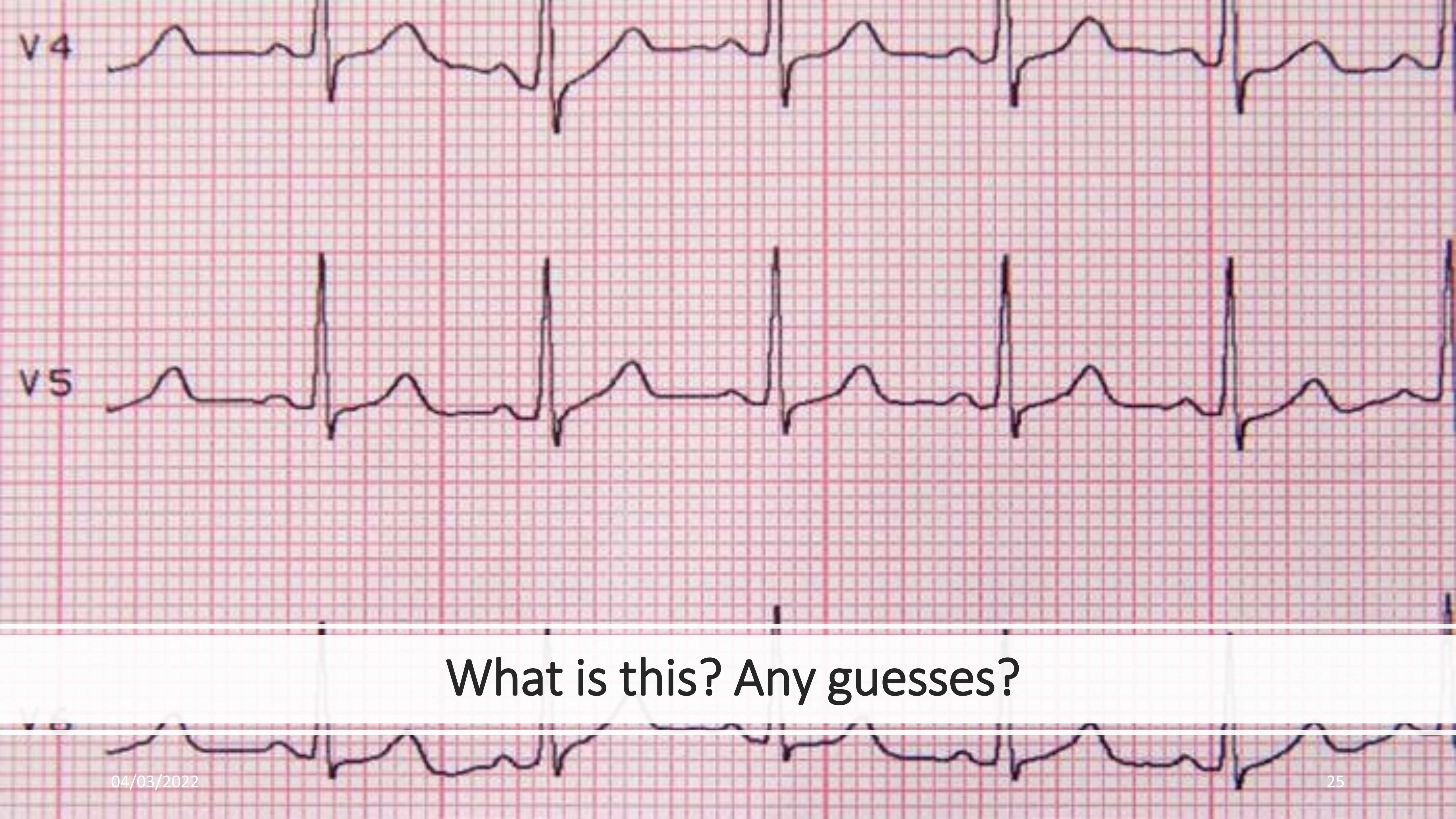
[NVIDIA Optical Flow SDK | NVIDIA Developer]

Result [7]: Automated Action Clustering



Just a nice try!

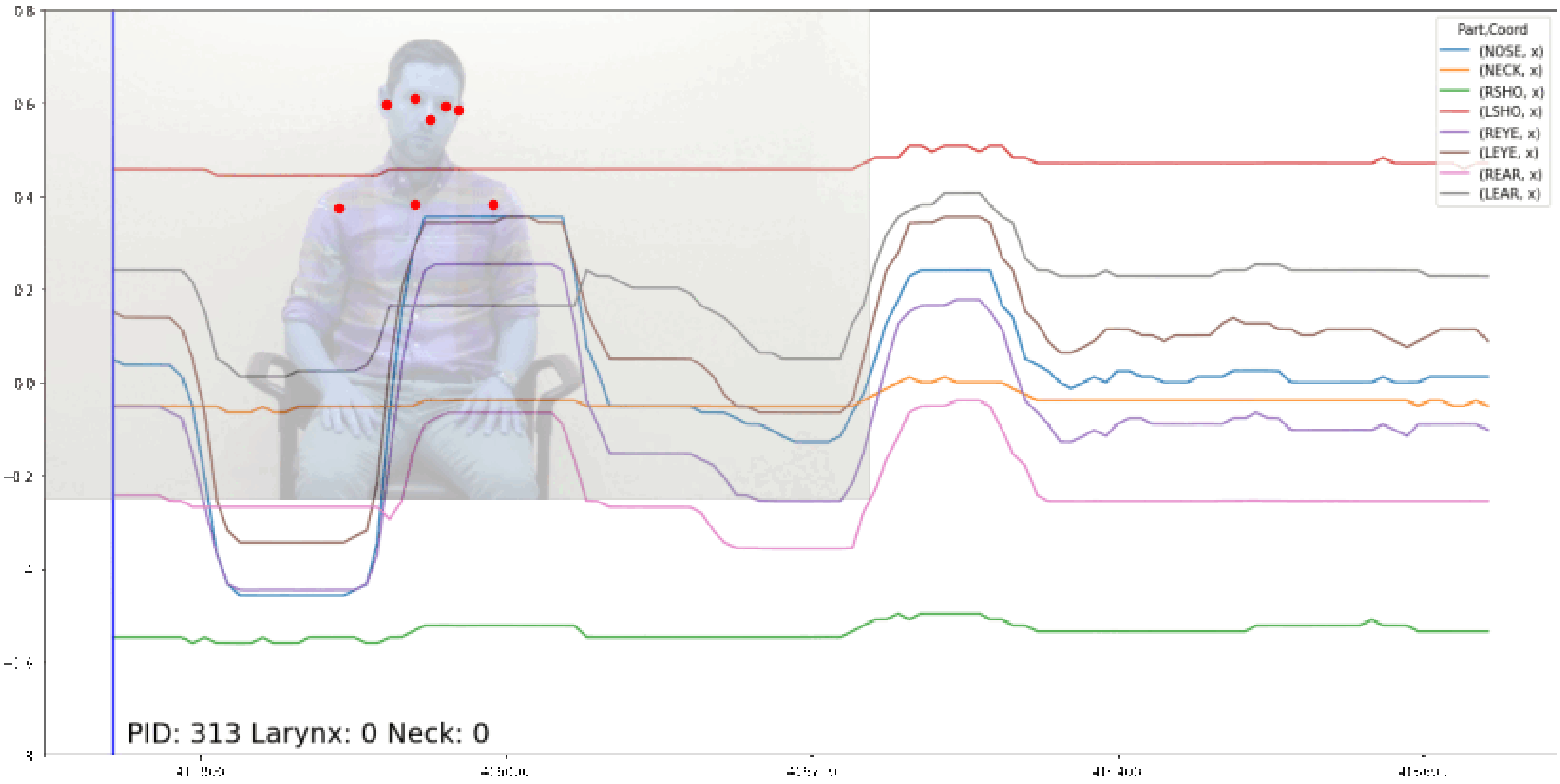
Fallback to Human Intelligence.



What is this? Any guesses?

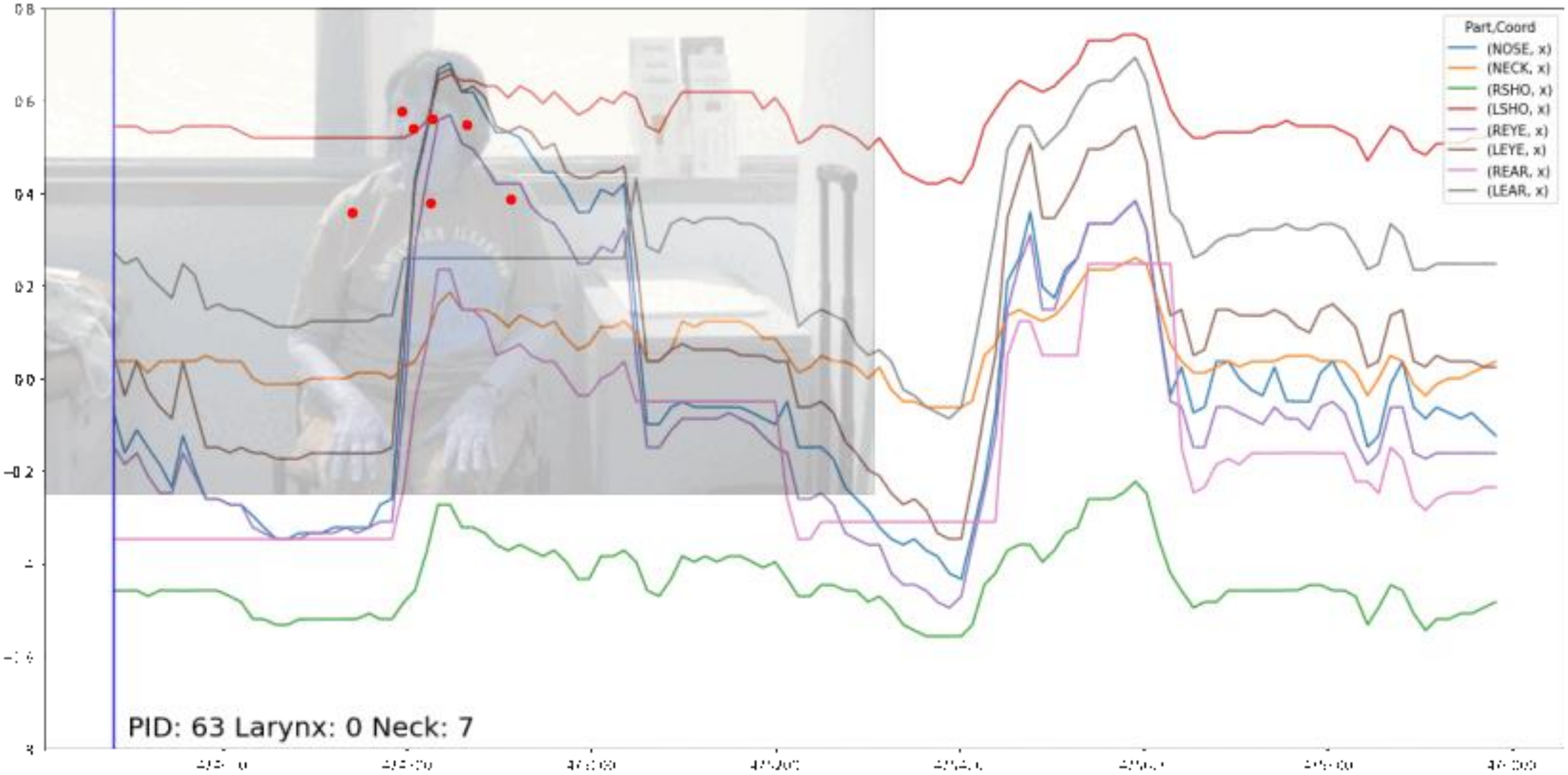
Results [8]: KP Visualization

X-Coordinate deviation



Time ->

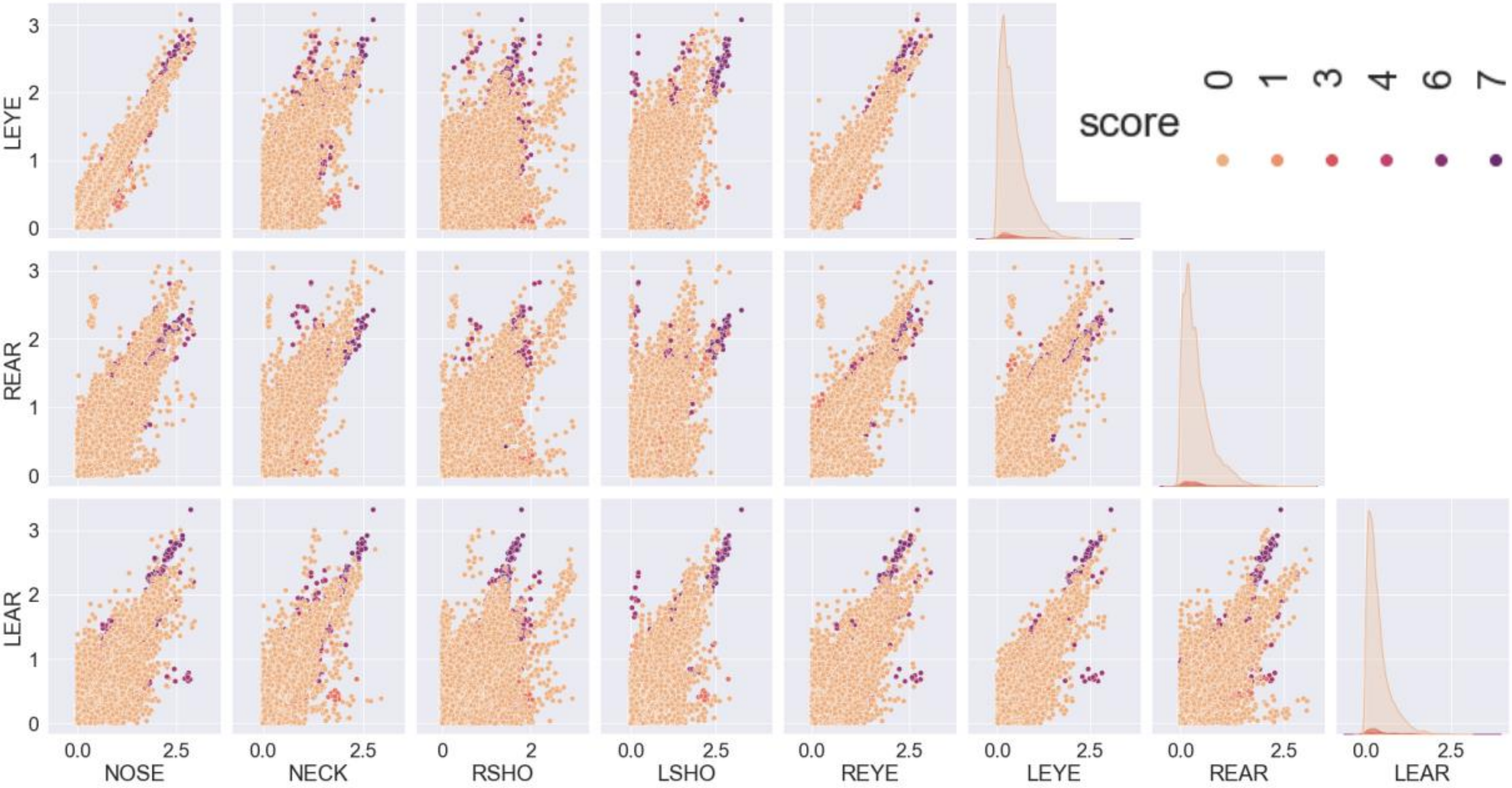
Can you notice a difference?



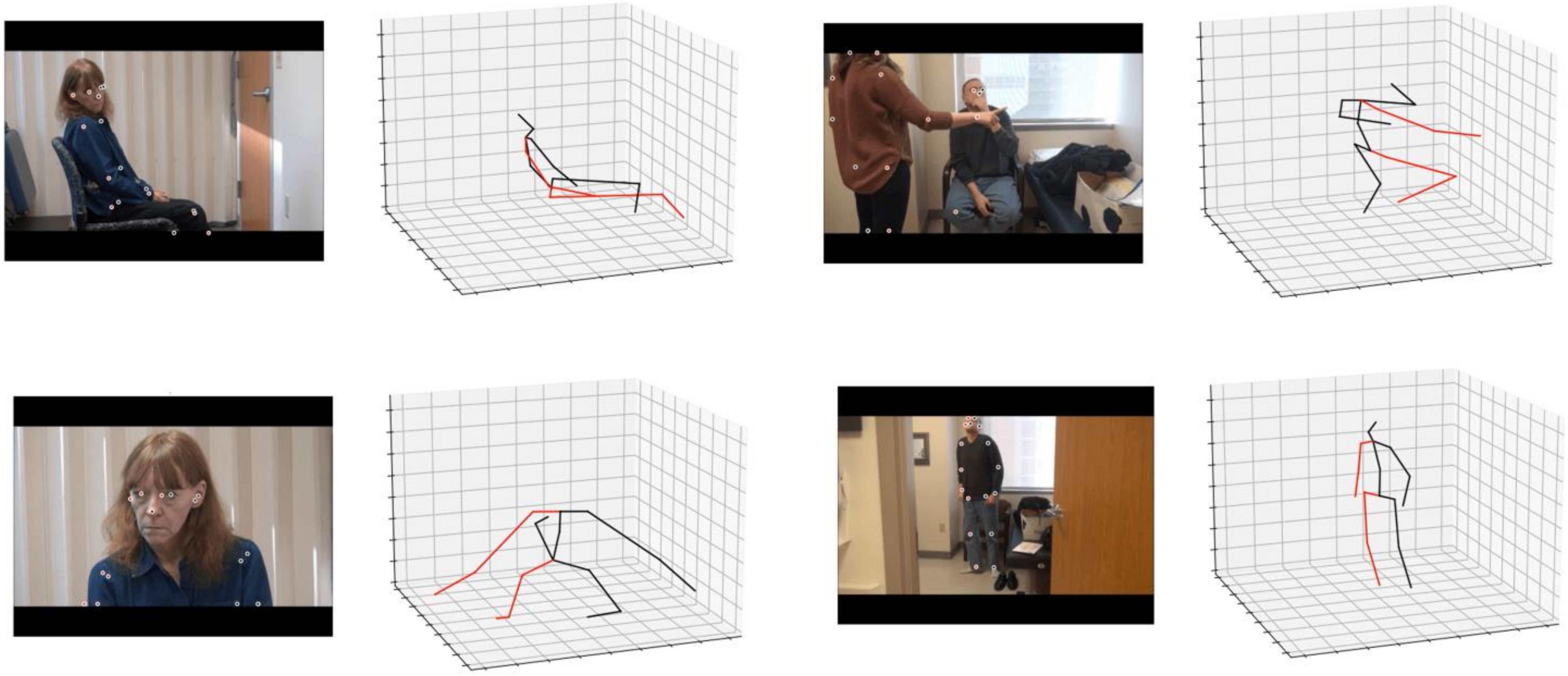
X-Coordinate deviation

Time ->

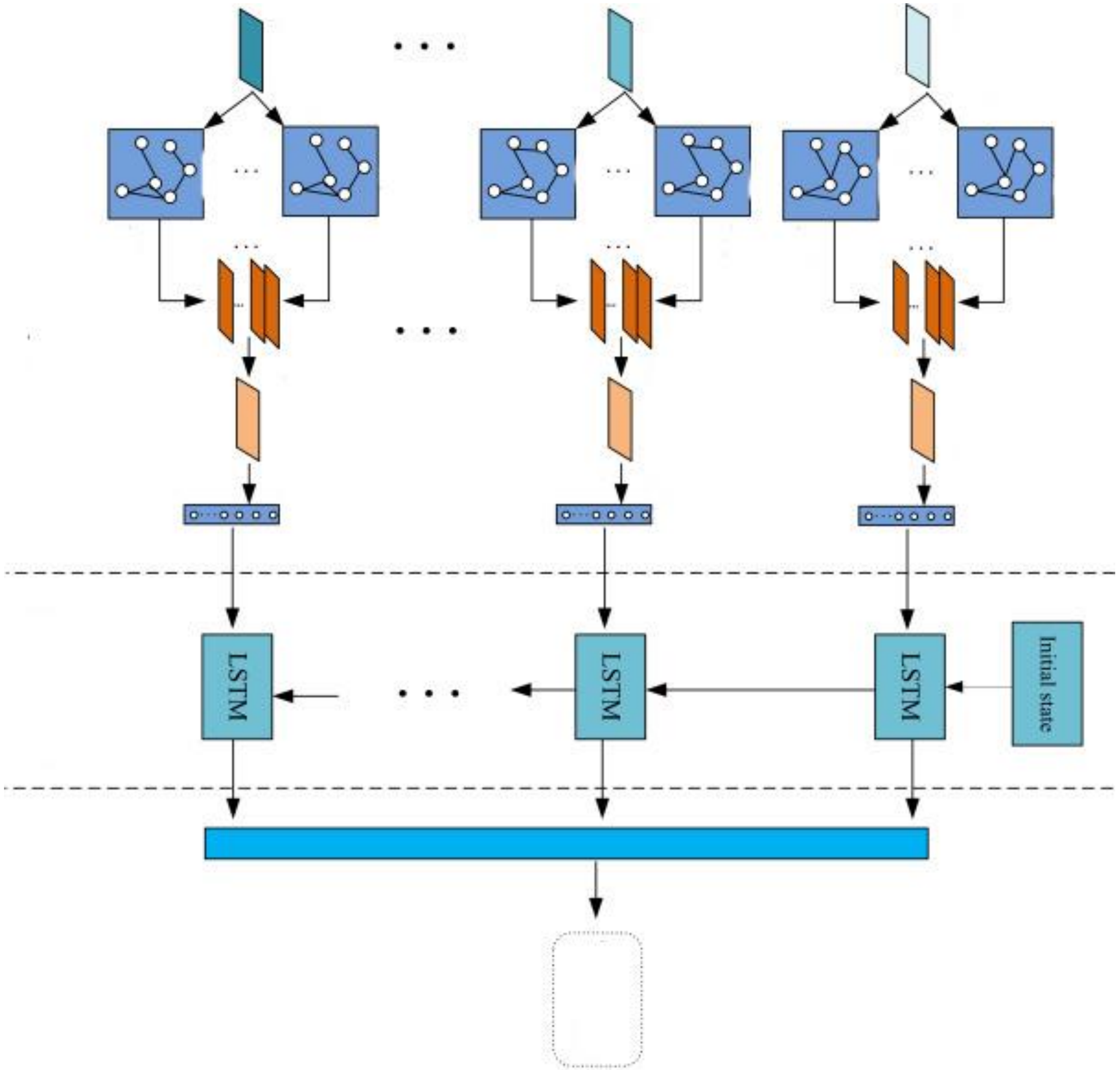
Results [9]: Deviation Correlation



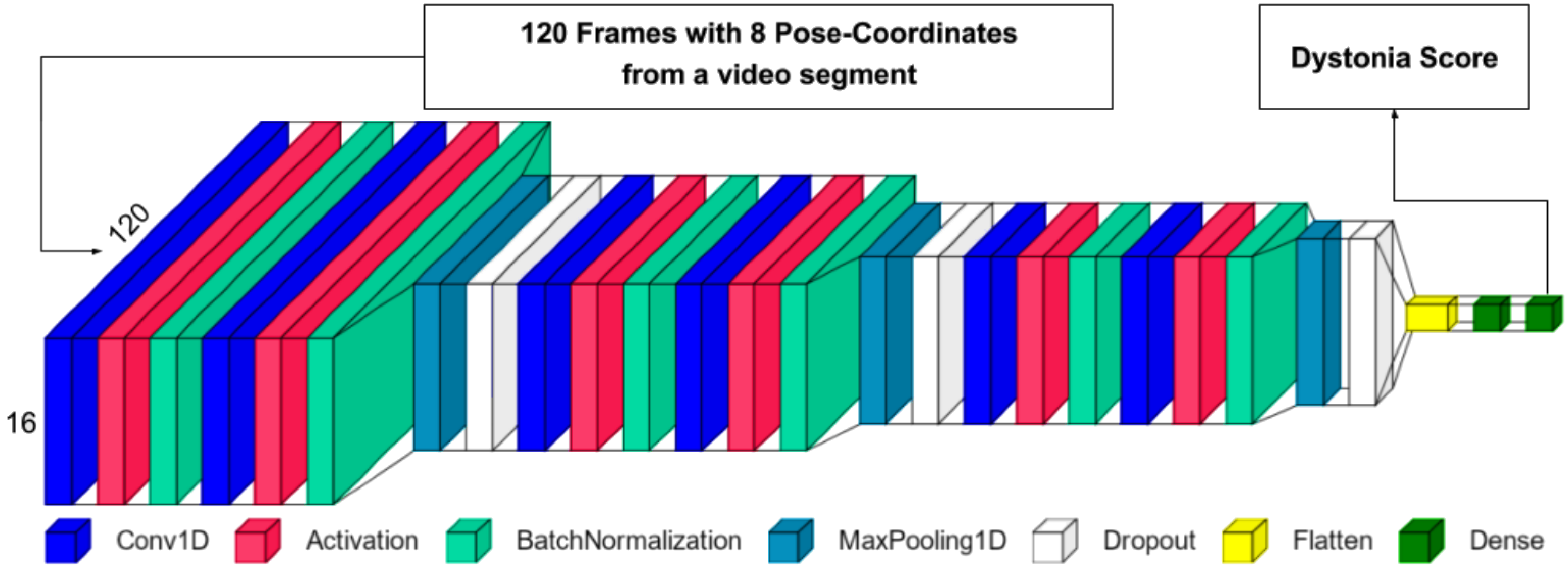
Failed Result [10]: VideoPose3D



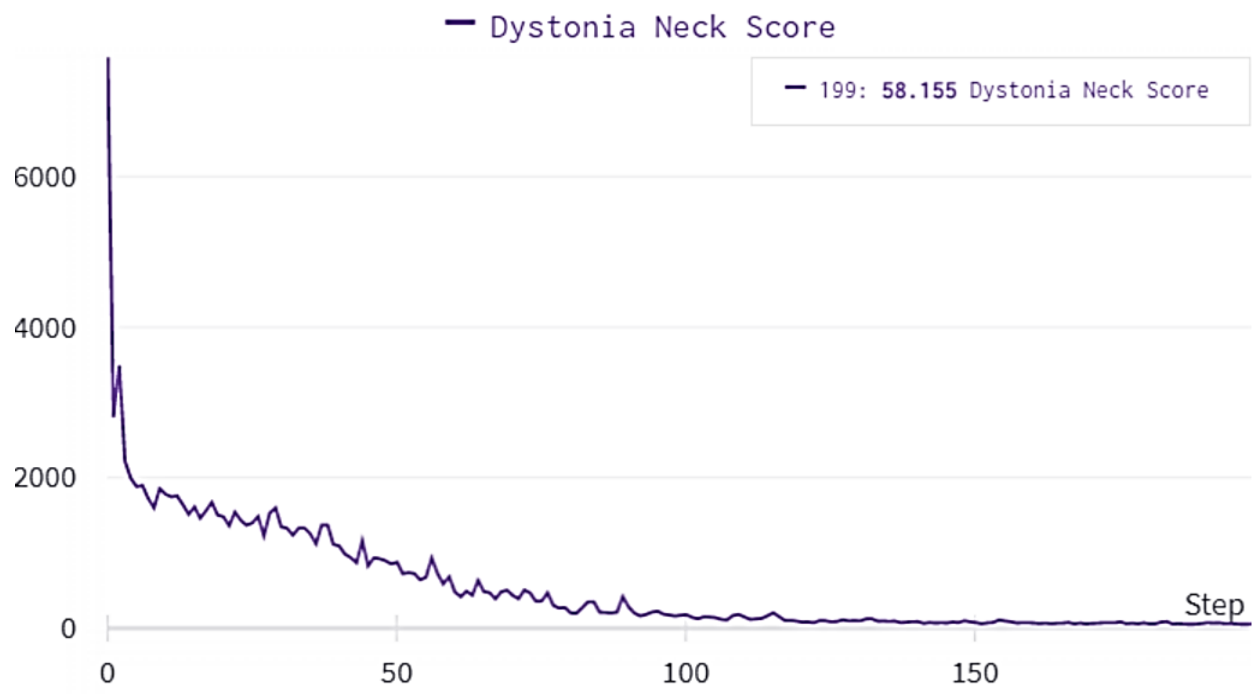
Failed Model: GC-LSTM

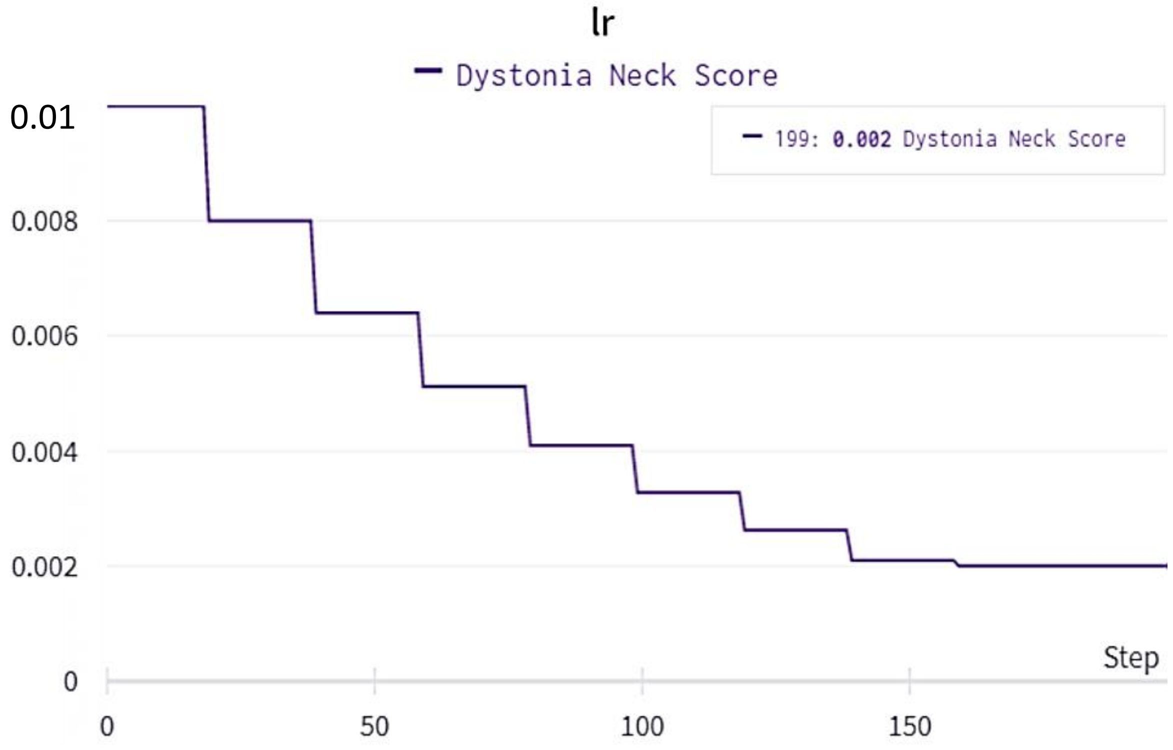


Used Model[11]: CNN Architecture

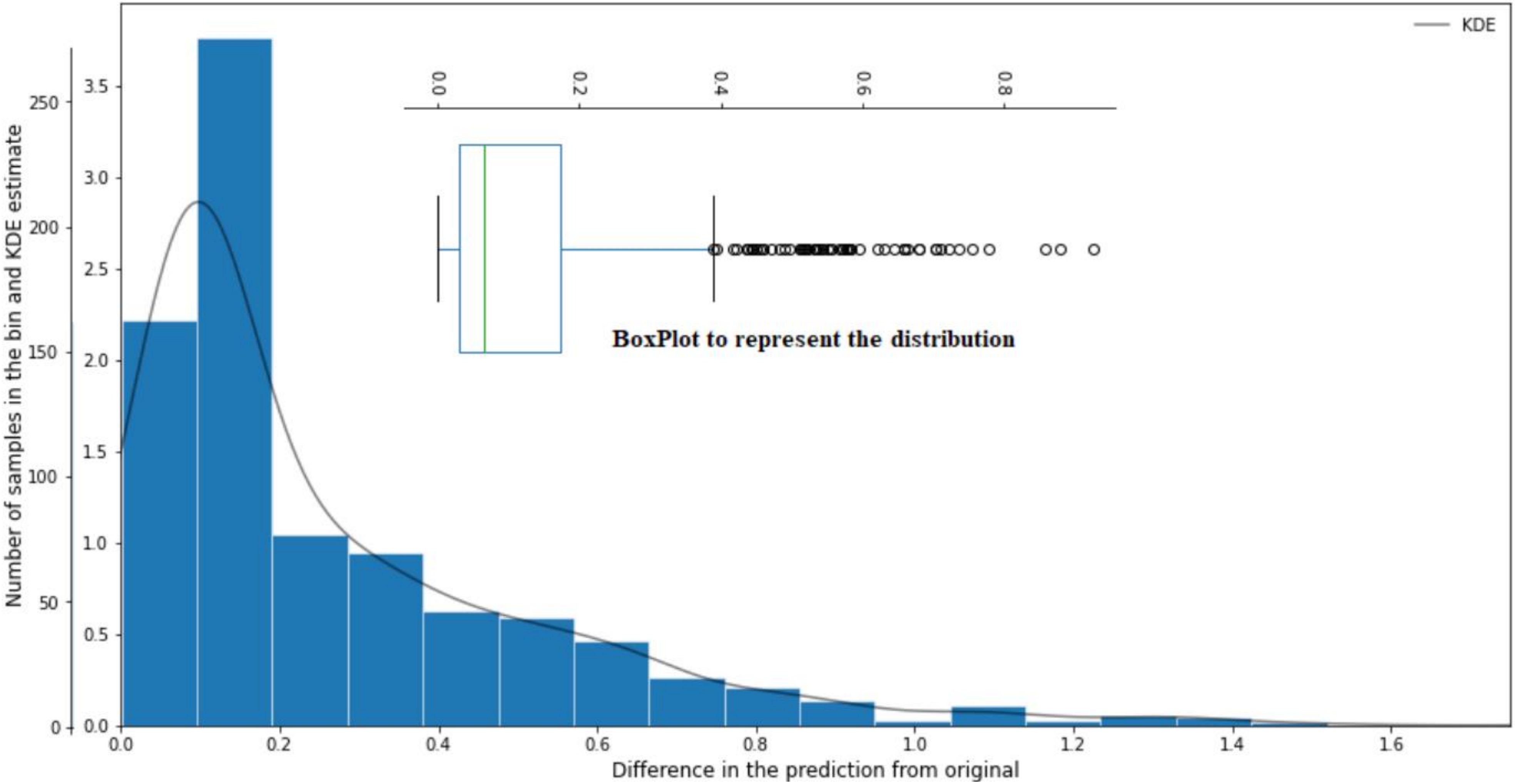


Result [12]: CNN Training

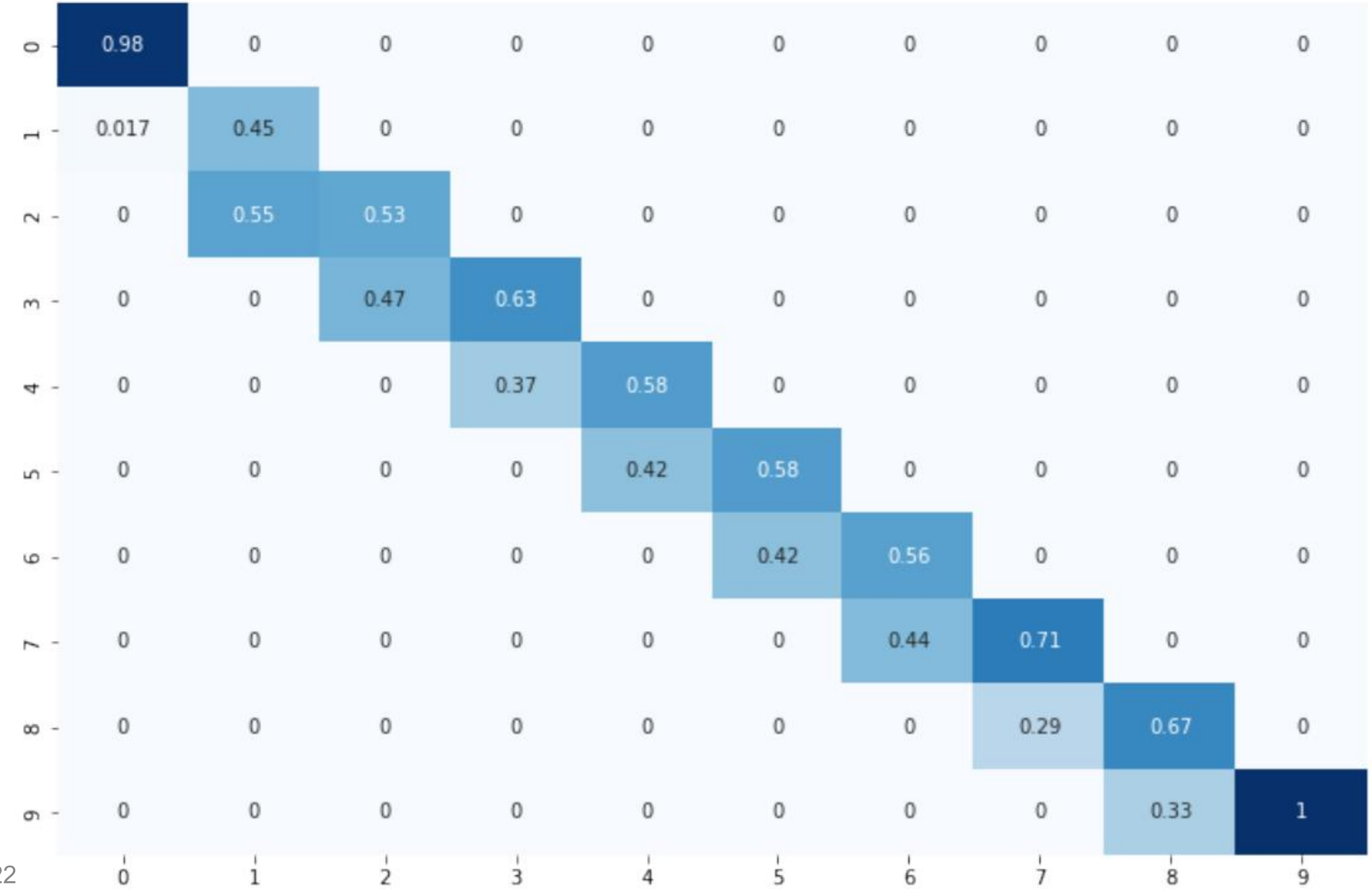




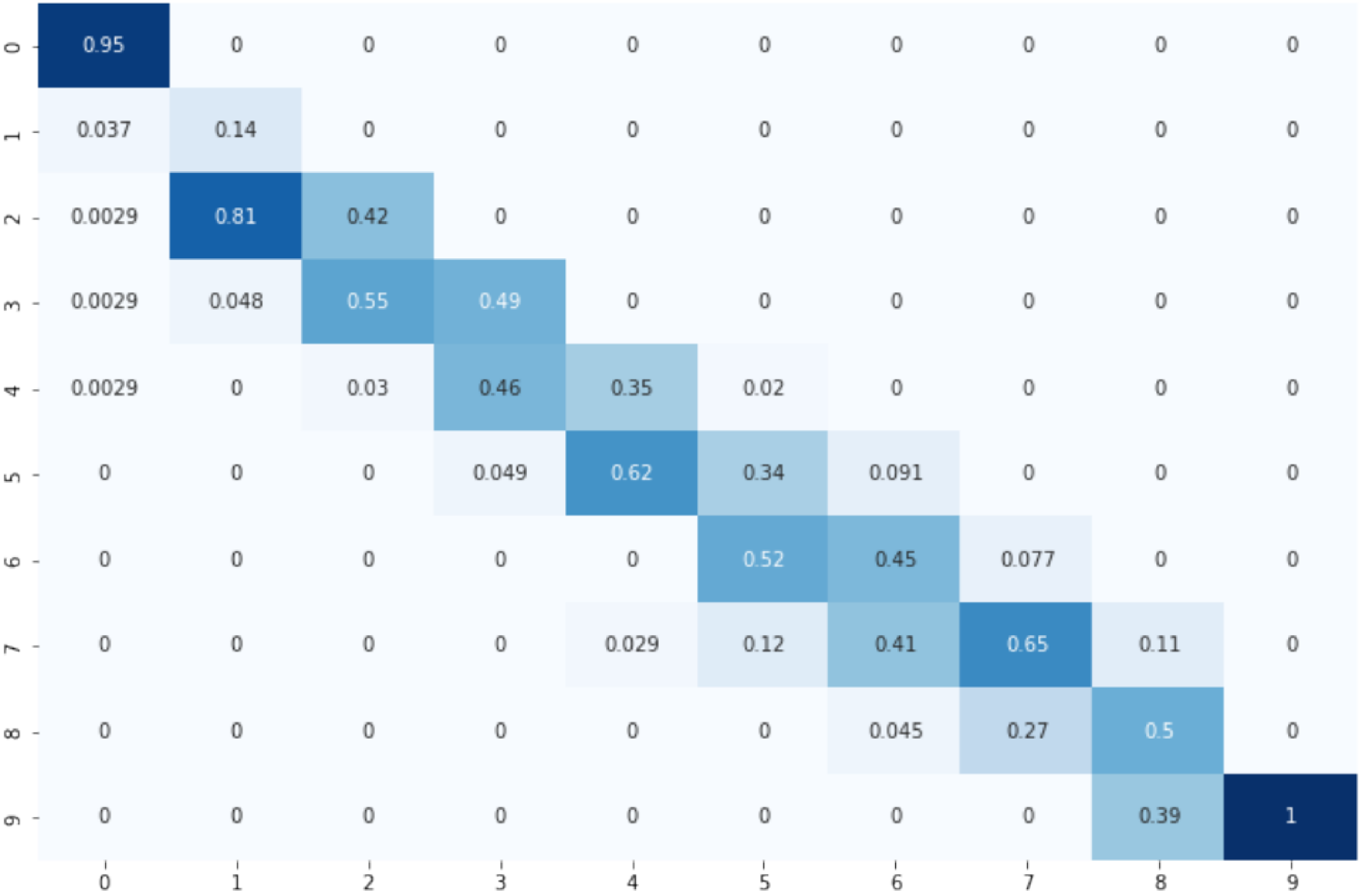
Result [13]: CNN Evaluation

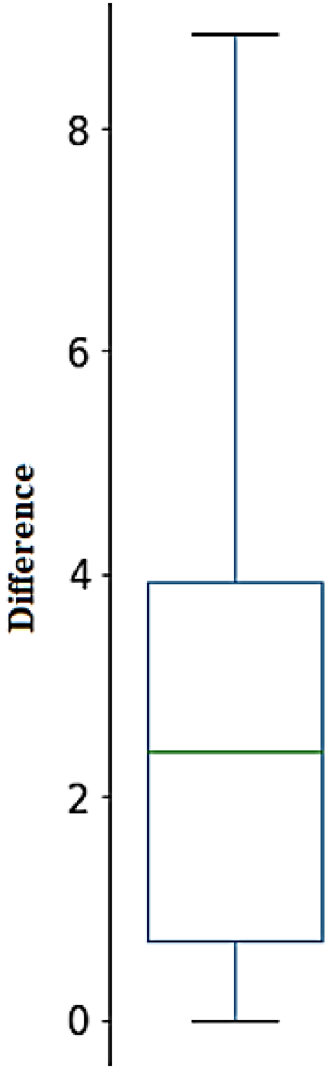


Result [14]:Class wise performance

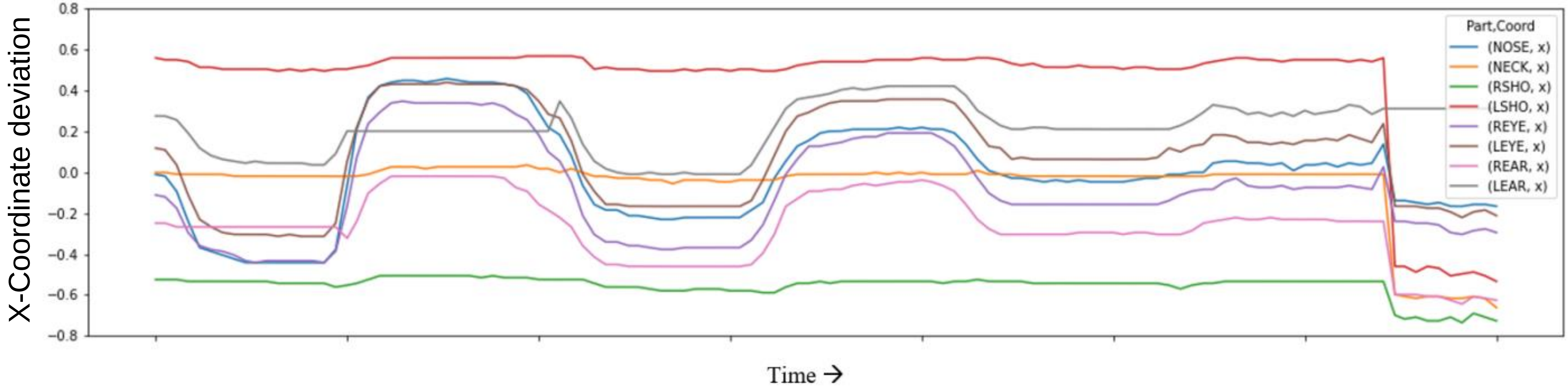


Result [15]:Best of the 5-Fold Model





Discussion [16]: 1/100 FPS sampling



Abnormality in the multi-line plot

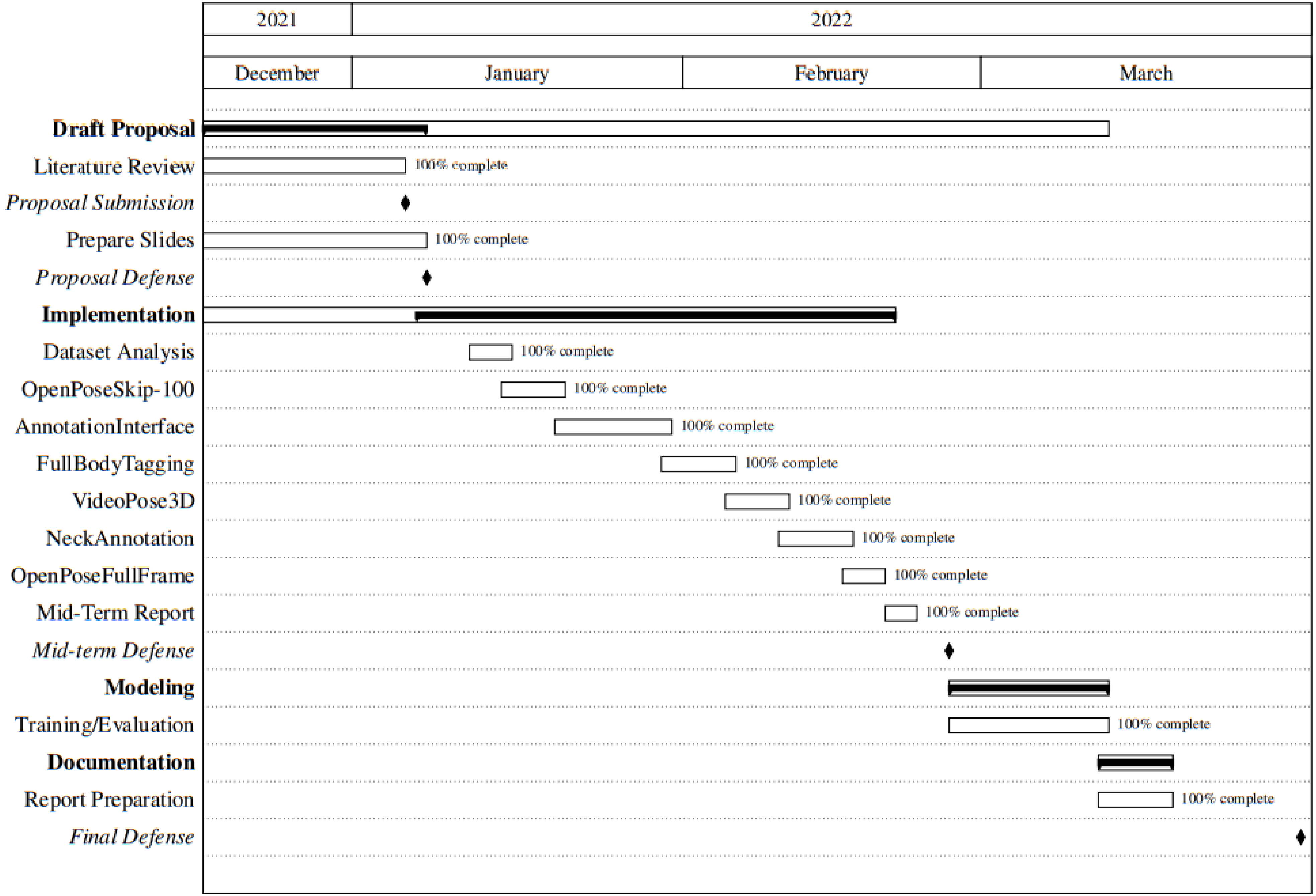
Future Enhancements

- New algorithms/models for:
  - replace Pose Estimations by OpenPose, 3D based models
  - person tracing; handle occlusion
  - for score prediction; different scores
- More data
  - with standardized protocol, uniform
  - for validations as well as training
- Action recognition; semi/auto video segment annotation
  - use of audio in the video

Conclusion

- video processing pipeline for posed based method
  - to process the clinical videos of dystonia patient
  - including FPS, spatial and temporal normalization.
  - used OpenPose for Dystonia Coalition video (first-time)
- used CNNs to predict neck dystonia scores
  - with 5-fold cross validation
- high hopes for CV methods for automatic assessment

Project Schedule



References[1]

[1] Kidziński, Łukasz, et al. "Deep neural networks enable quantitative movement analysis using single-camera videos." *Nature communications* 11.1 (2020): 1-10.

[2] Prince, John. *Objective assessment of Parkinson's disease using machine learning*. Diss. University of Oxford, 2018.

[3] Li, Michael. *Objective Vision-Based Assessment of Parkinsonism and Levodopa-Induced Dyskinesia in Persons with Parkinson's Disease*. Diss. University of Toronto (Canada), 2017.

[4] H. A. Jinnah. Diagnosis & Treatment of Dystonia. Neurol. Clin., 33(1):77, Feb 2015.

References[2]

[5] Al-Faris, Mahmoud, et al. "A review on computer vision-based methods for human action recognition." *Journal of Imaging* 6.6 (2020): 46.

[6] Kwon, Young-Tae, et al. "Soft Material-Enabled, Active Wireless, Thin-Film Bioelectronics for Quantitative Diagnostics of Cervical Dystonia." *Advanced materials technologies* 4.10 (2019): 1900458.

[7] Valeriani, Davide, and Kristina Simonyan. "A microstructural neural network biomarker for dystonia diagnosis identified by a DystoniaNet deep learning platform." *Proceedings of the National Academy of Sciences* 117.42 (2020): 26398-26405.