ML based eye closure estimation algorithm, as a foundation for Bell's palsy treatment

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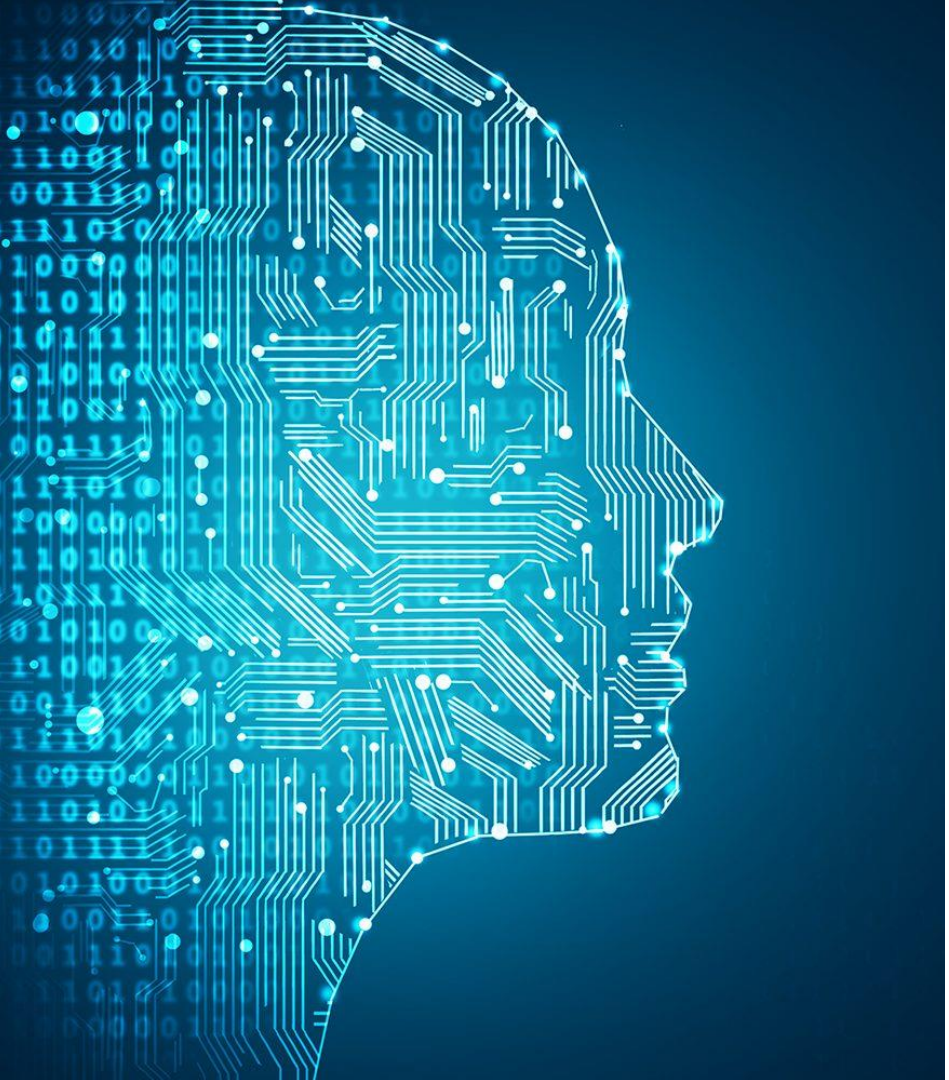
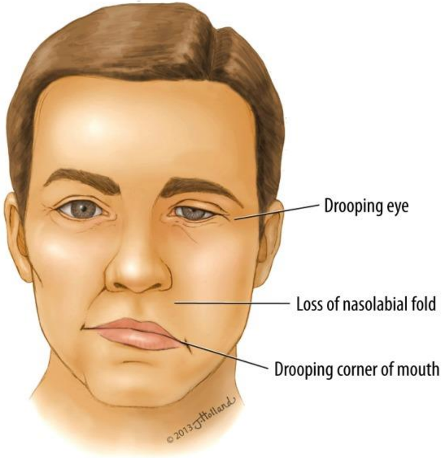


Outline

- Motivation
- Our Vision
- Research Question
- Project Milestones and Results
- Summary

Motivation

- **Bell's palsy** – the most common facial paralysis
- Symptoms include problems **with blinking and closing the eye**
- This would leave the cornea dry, which cause **pain, infections and even lead to blindness.**
- Peak ages are 15 - 45 years, <u>rapid rehabilitation is crucial!</u>



NO available solutions which are not invasive and effective in advanced stages!

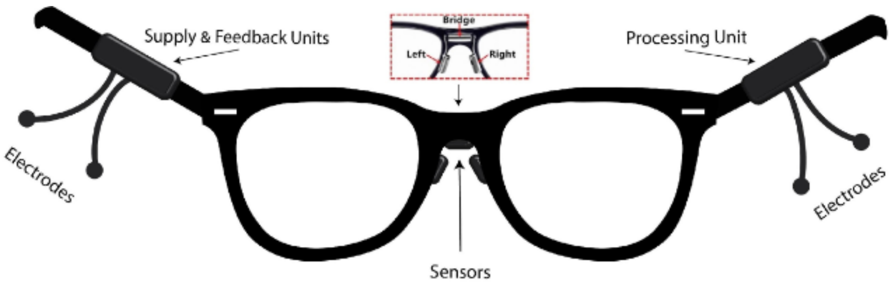
Our Vision

1. Detecting blinks from the healthy eye and paralyzed eye

2. Applying synchronized and minimal electrical stimulation on the paralyzed eye, accelerating rehabilitation

HOW?

- ❑ Detecting eyes closure **amount**
- ❑ Once a blink is reached from the ***healthy eye***, check the closure amount of the ***paralyzed* eye** and stimulate it to reach a full closure



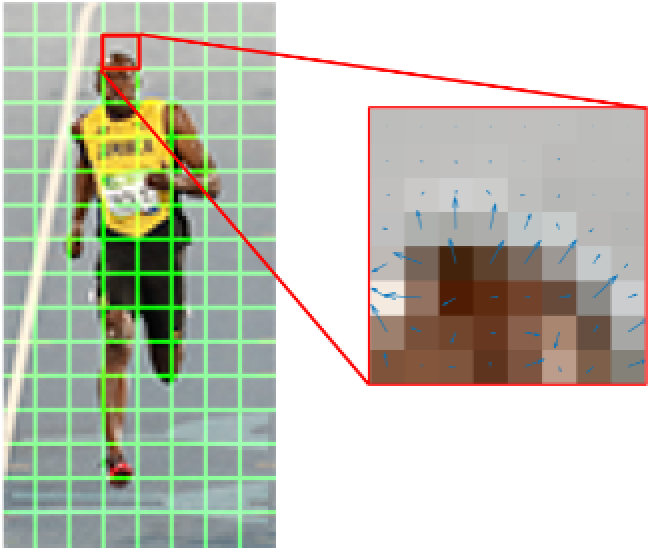
The Research Question

Does using advanced methods of **machine learning**, applied on a **visual input** from video cameras, apply for a reliable estimation of **human eye closure amount**?

Project Milestones

Project Milestones
Eye Detection

Detecting faces using Python's HOG-based detector, implemented in dlib



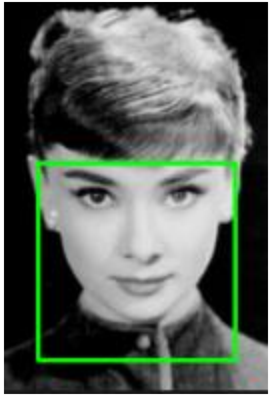
2	3	4	4	3	4	2	2
5	11	17	13	7	9	3	4
11	21	23	27	22	17	4	6
23	99	165	135	85	32	26	2
91	155	133	136	144	152	57	28
98	196	76	38	26	60	170	51
165	60	60	27	77	85	43	136
71	13	34	23	108	27	48	110

Gradient Magnitude

80	36	5	10	0	64	90	73
37	9	9	179	78	27	169	166
87	136	173	39	102	163	152	176
76	13	1	168	159	22	125	143
120	70	14	150	145	144	145	143
58	86	119	98	100	101	133	113
30	65	157	75	78	165	145	124
11	170	91	4	110	17	133	110

Gradient Direction

python™

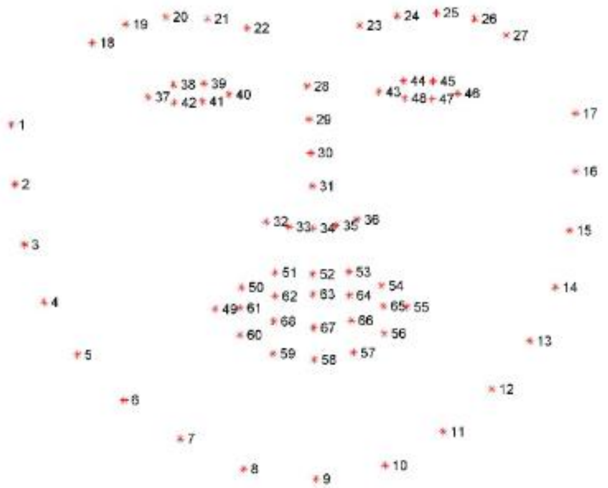


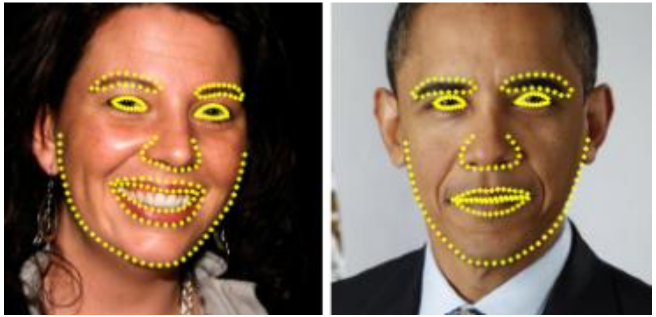
N. Dalal and B. Triggs. Histograms of oriented gradients for human detection. In CVPR, 2005.

Project Milestones

Eye Detection – cont.

- Once a bounding box is found, it is easier to extract landmarks out of it
- Using a pre-trained facial landmarks detector (created by regression trees)

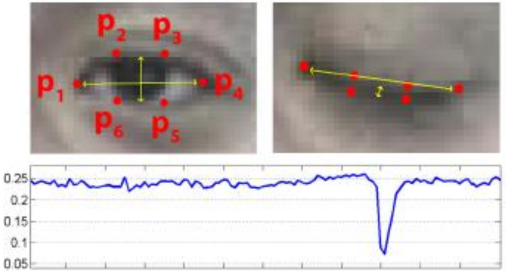




V. Kazemi and S. Josephine. One millisecond face alignment with an ensemble of regression trees. In CVPR, 2014.

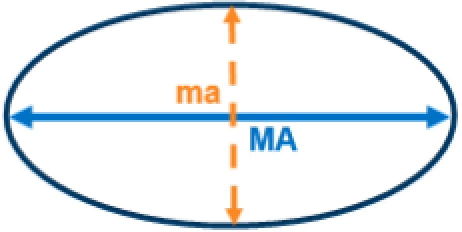
Project Milestones
Feature Extraction

EAR – Eye Aspect Ratio



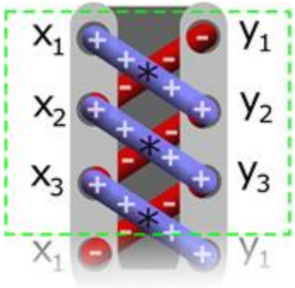
$$EAR = \frac{||p_2 - p_6|| + ||p_3 - p_5||}{2||p_1 - p_4||}$$

Ellipse Area



$$A_{ellipse} = \pi \cdot ma \cdot MA$$

Shoelace Formula

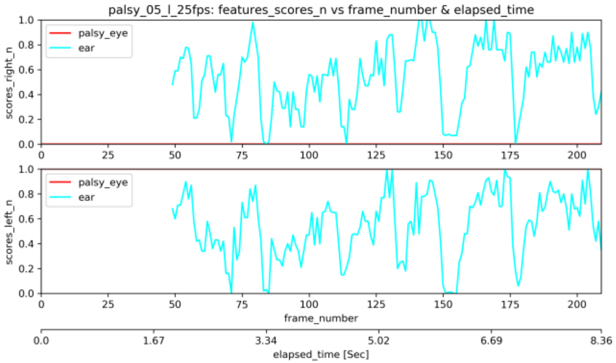


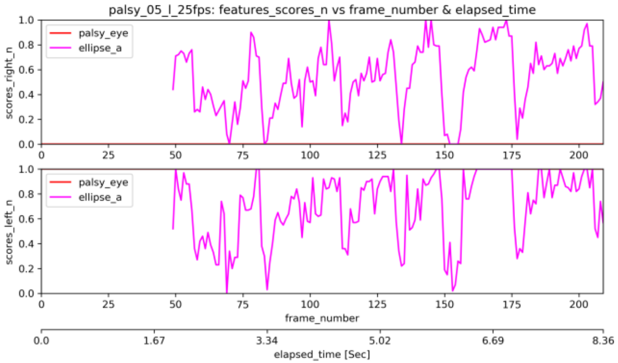
$$A = \frac{1}{2}\left|\sum_{i=1}^{n-1} x_i y_{i+1} + x_n y_1 - \sum_{i=1}^{n-1} x_{i+1} y_i - x_1 y_n\right|$$

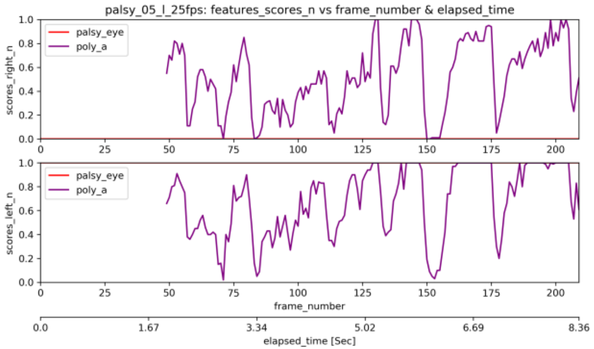
- Blink duration: 300-400ms (~10 frames); one blink every 2-10 seconds (source: Wikipedia)
- All features are **normalized** with respect to the scores of the previous frames

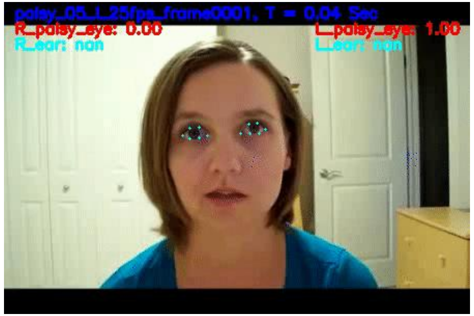
Project Milestones

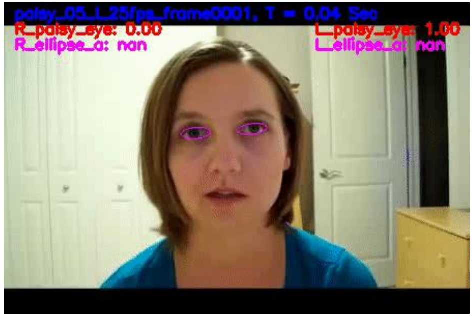
Feature Extraction – cont.





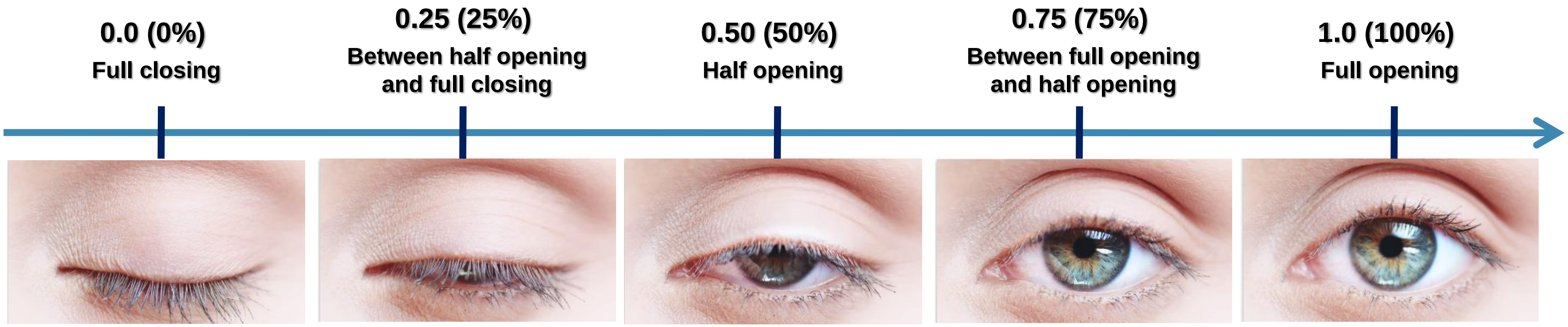






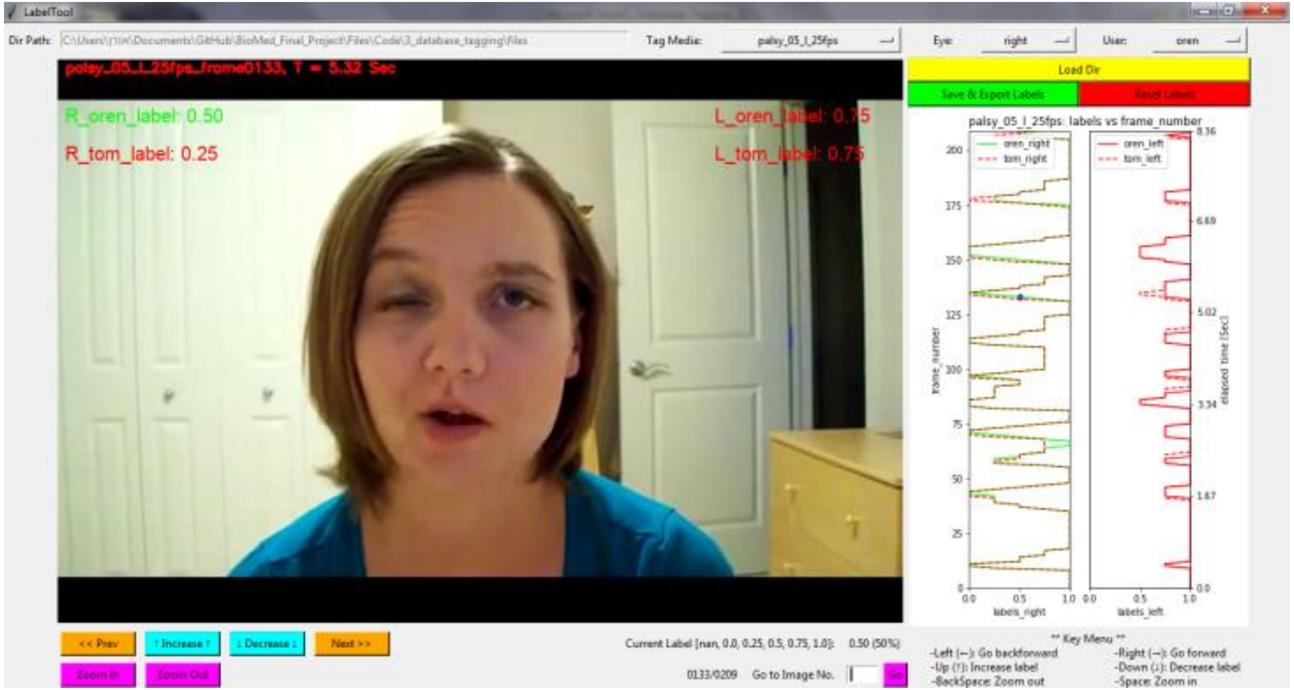
Project Milestones
Tagging Data

- Tagging frames for supervised learning (for Training Classifier)
- Suggest a discrete scale for tagging (5 Levels)



Project Milestones (Tagging Data – cont.)

- Build a semi-automatic GUI to make the tagging work easier (subjective tagging)



Project Milestones

Training Classifiers

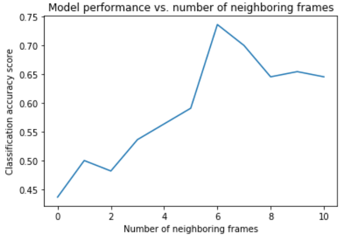
- Using 300-VW dataset for healthy patients and YouTube videos for ‘paralyzed’ patients
- Each video lasts about 8 to 10 seconds, using 25-30 frames per second
- A total of 436 blinks, using 5-level manual tagging
- A total of 19,182 samples
- <u>A total of 5,115 samples as the final database</u>

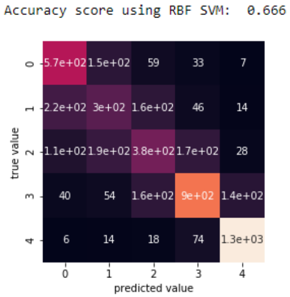
Label	0	0.25	0.5	0.75	1
Healthy patients	464	388	419	570	610
Patients diagnosed with Bell's Palsy	354	351	461	730	768
Total	818	739	880	1300	1378

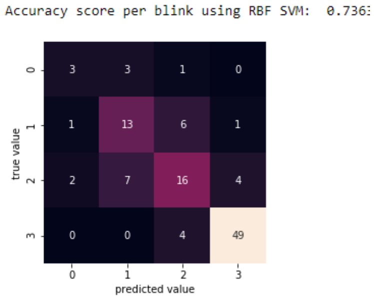
# Blinks	Men	Women
Healthy patients	107	107
Patients diagnosed with Bell's Palsy	111	111

Project Milestones

Training Classifiers – cont.





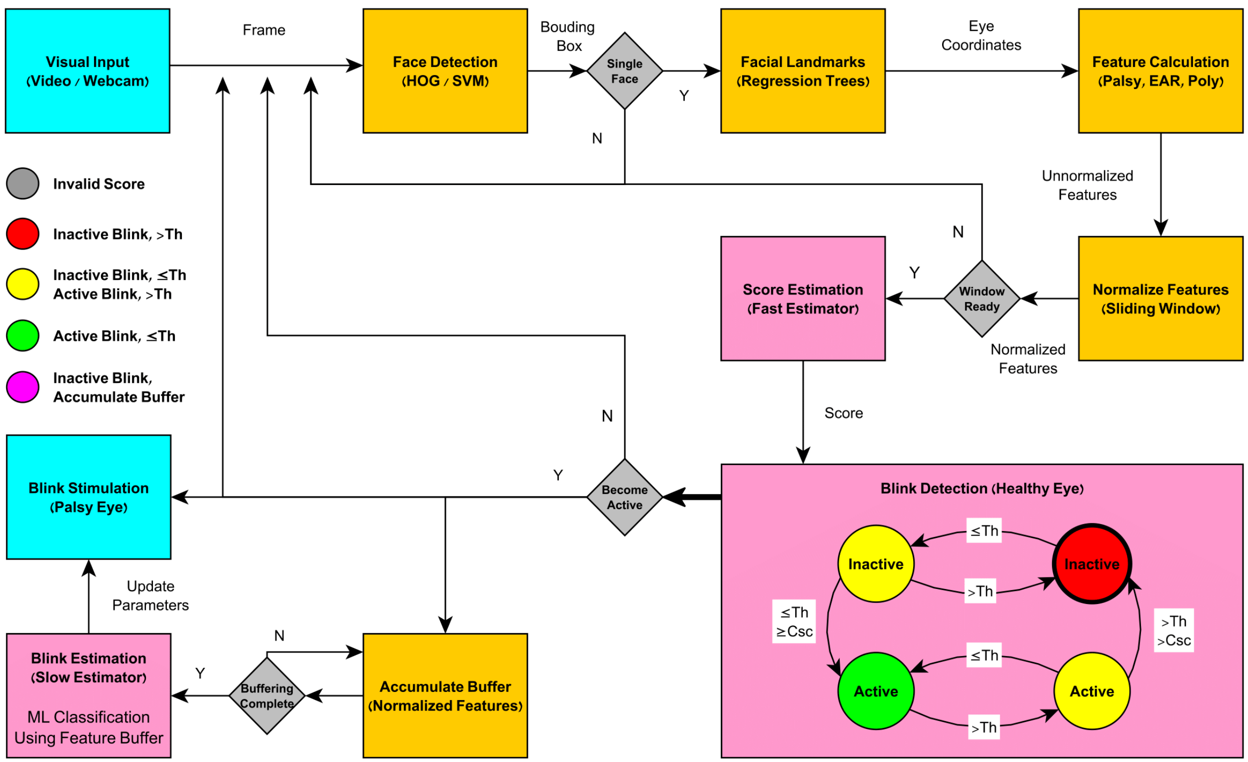


- Using features from **12** neighboring frames (6 before + 6 after)
- Total number of features: **27**
- Performance evaluation:
  - Accuracy per frame
  - Accuracy per blink (the minimum label in the current blink)
  - Using 5-fold cross validation with random blink numbers

Using 3-level classification: up to 81.9% (frame-wise) and 91.8% (blink-wise)

Method	Accuracy per frame	Accuracy per blink
Gaussian Naïve Bayes	49.9%	40.9%
K-NN (k=3)	64.5%	70%
SVM; Linear Kernel	54.7%	45.4%
SVM; RBF Kernel	**66.7%**	**73.6%**
Random Forest	68.9%	73.6%
SVM RBF + HOG features	52.6%	58.2%
K-NN + HOG features (k=11)	58.5%	70.9%

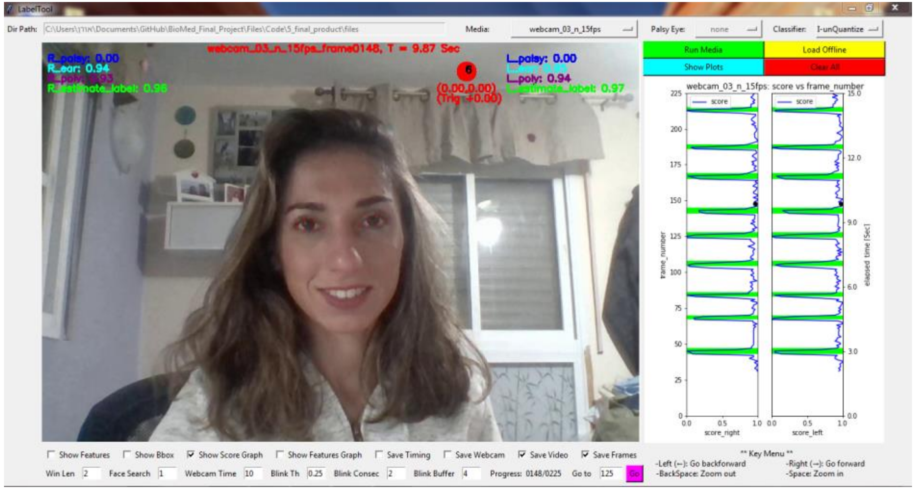
Project Milestones (Final Integration)

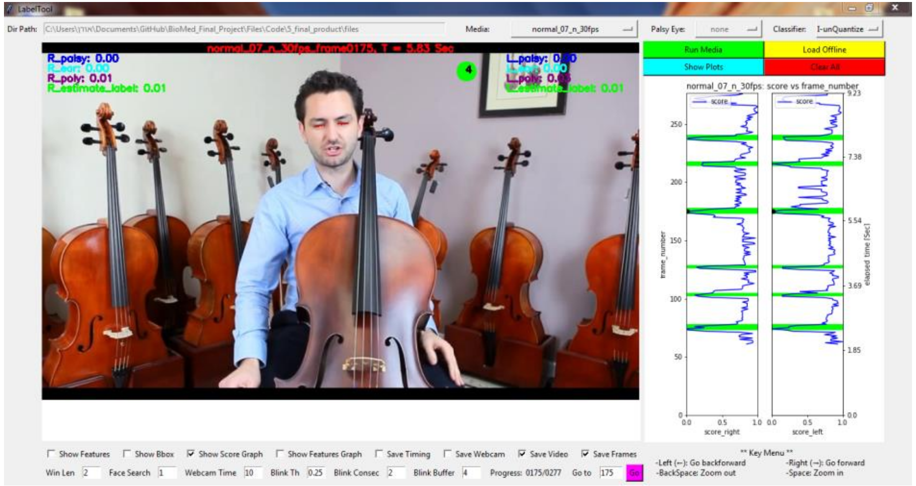


Tom

Project Milestones (Final Integration – cont.)

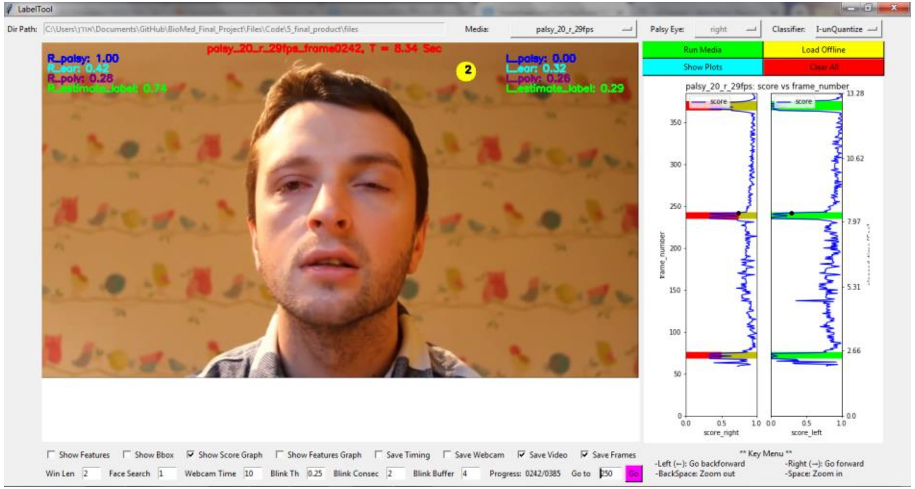
- Performance Illustration for **Healthy people**

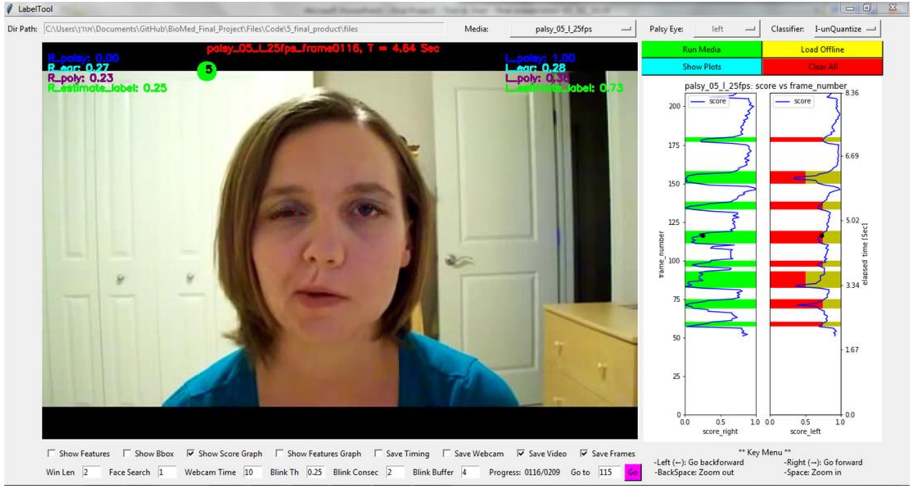




Project Milestones (Final Integration – cont.)

- Performance Illustration for **Palsy people**





Summary

- We introduce a novel technique for assessing the paralyzed eye's amount of closure, that can be used for future diagnosis and treatment
- The application is based on basic calculations, making it suitable for real-time applications
- By integration of "fast" and ”slow" estimators, we reached ~75% accuracy. This can be further improved by:
  - Using more accurate eye detectors
  - Increasing the database
  - Using higher resolution and frame rate
  - Applying more sophisticated ML methods (e.g. deep learning)

Thank You!

Questions?