College of Health Solutions
Arizona State University

EMBEDDED MACHINE INTELLIGENCE LAB

Mobile App Based in Home Parkinson Disease Management

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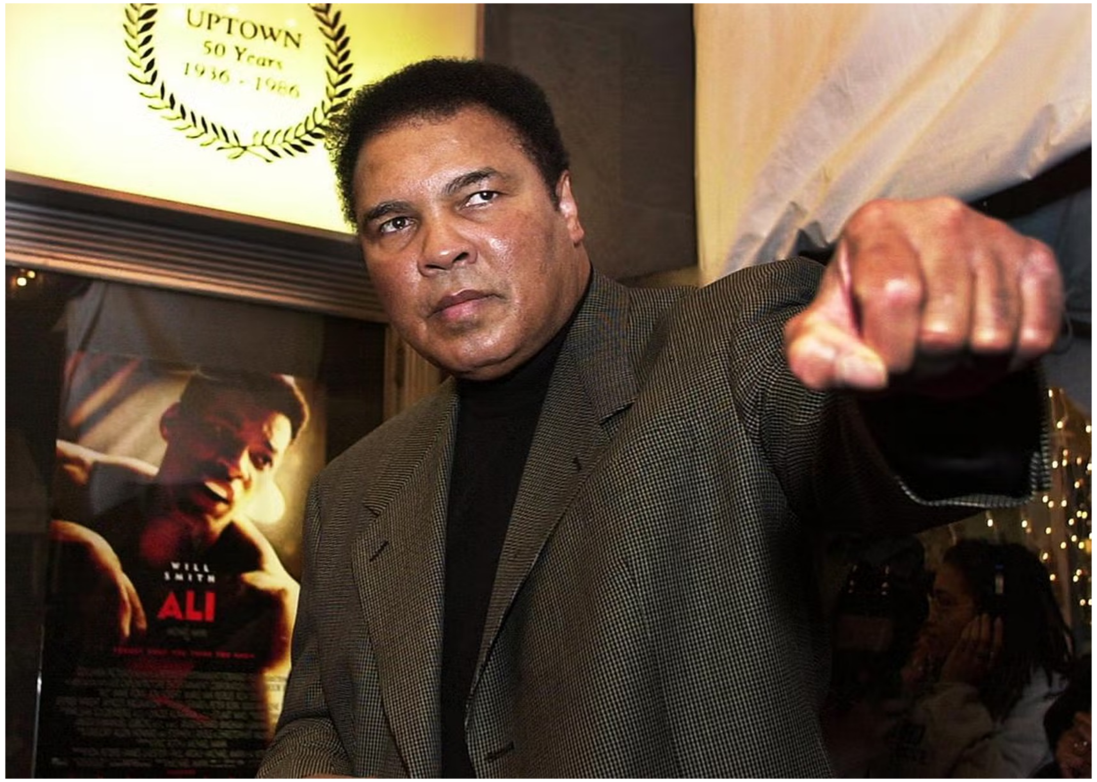
Outline

- What is the problem (PD)?
- Significance of wearables in PD space
- App Design
    - Design decisions
    - Symptoms
    - In-home monitoring
    - Sensor data collection
    - App activities and views
- Machine learning for prediction
- What is supervised learning?
- What is self-supervised learning?
- Results

Do you know about him?



https://slate.com/technology/2016/06/what-caused-muhammad-alis-parkinsons-disease-its-nearly-impossible-to-say.html

Parkinson Disease (PD)

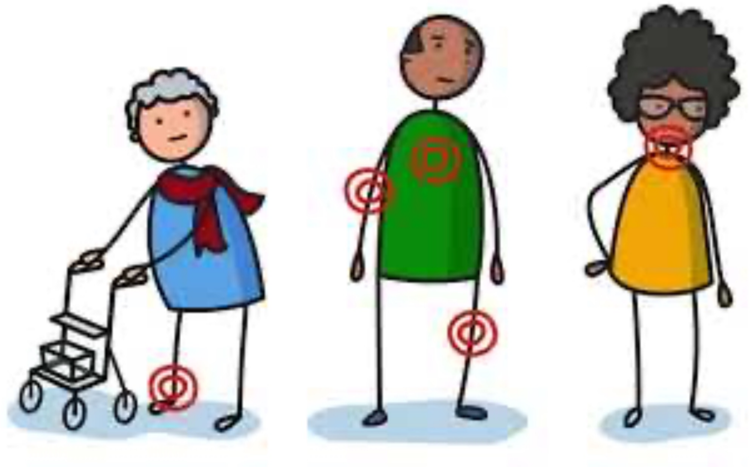
- Progressive disorder (Age>50)
- Affects the nervous system and the parts of the body controlled by the nerve

Common Symptoms:

- Tremors
- Gait & Balance Problem

  Freezing of Gait: A sudden and temporary inability to initiate or continue walking, as if their feet are glued to the ground.

- No cure



https://youtu.be/u_tozEV7fhttps://youtu.be/u_tozEV7f4k

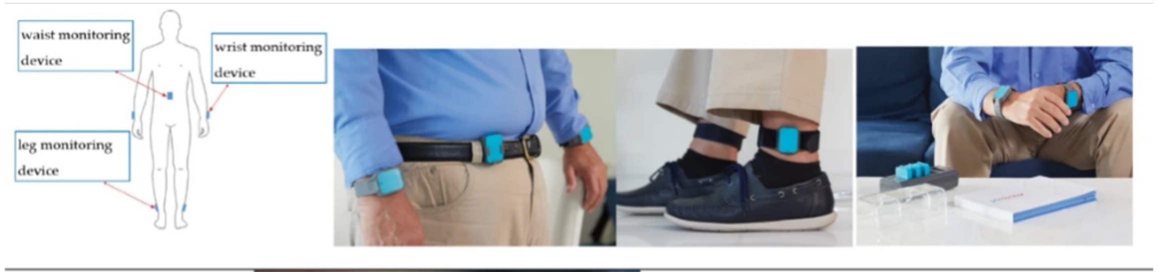
Wearables in PD

IMU Sensors (6D)

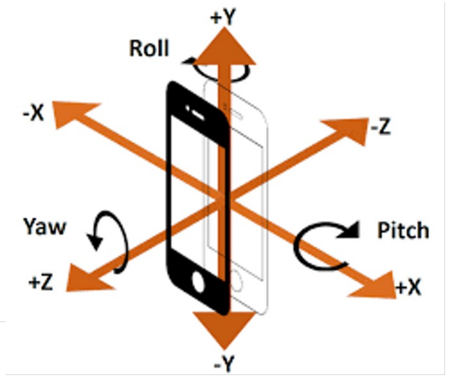
- *Accelerometer* (3D): Acceleration
- *Gyroscope* (3D): Angular velocity

- Extract Different Features (Velocity, and gait pattern, detect physiological biomarkers)

- Early PD Detection
- Detect deterioration for known PD patients



1 DEVICE



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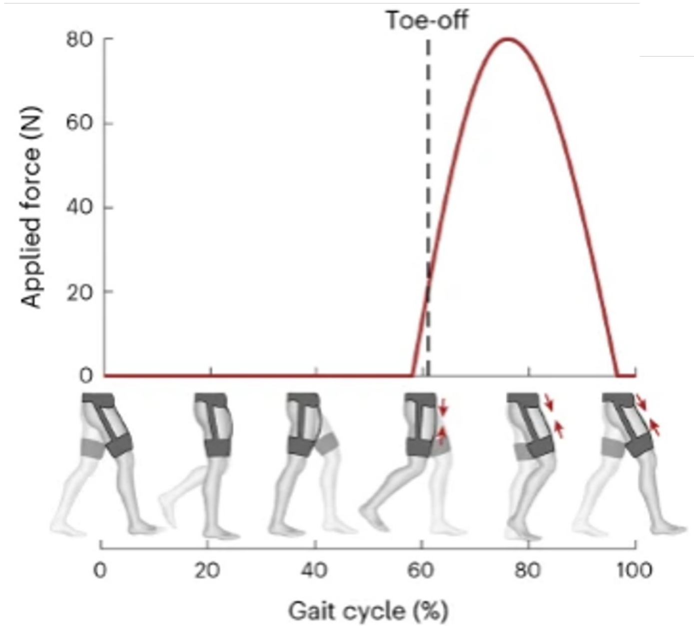
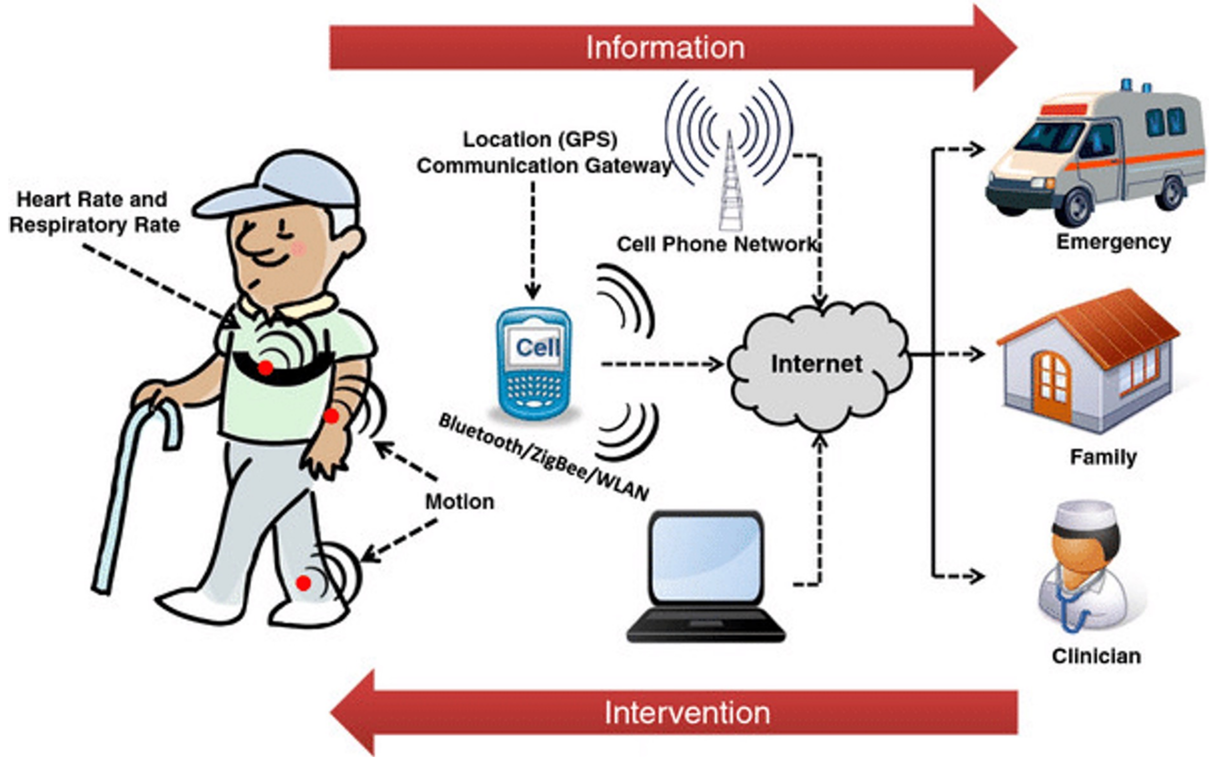


Moreau, C., Rouaud, T., Grabli, D. *et al.* Overview on wearable sensors for the management of Parkinson's disease. *npj Parkinsons Dis.* 9, 153 (2023). https://doi.org/10.1038/s41531-023-00585-y

Wearables in PD

Store the data collected by wearables into a cloud service



Patel S, Park H, Bonato P, Chan L, Rodgers M. A review of wearable sensors and systems with application in rehabilitation. *J Neuroeng Rehabil*. 2012;9:21. Published 2012 Apr 20. doi:10.1186/1743-0003-9-21

App Design

There are 2 features to be implemented.

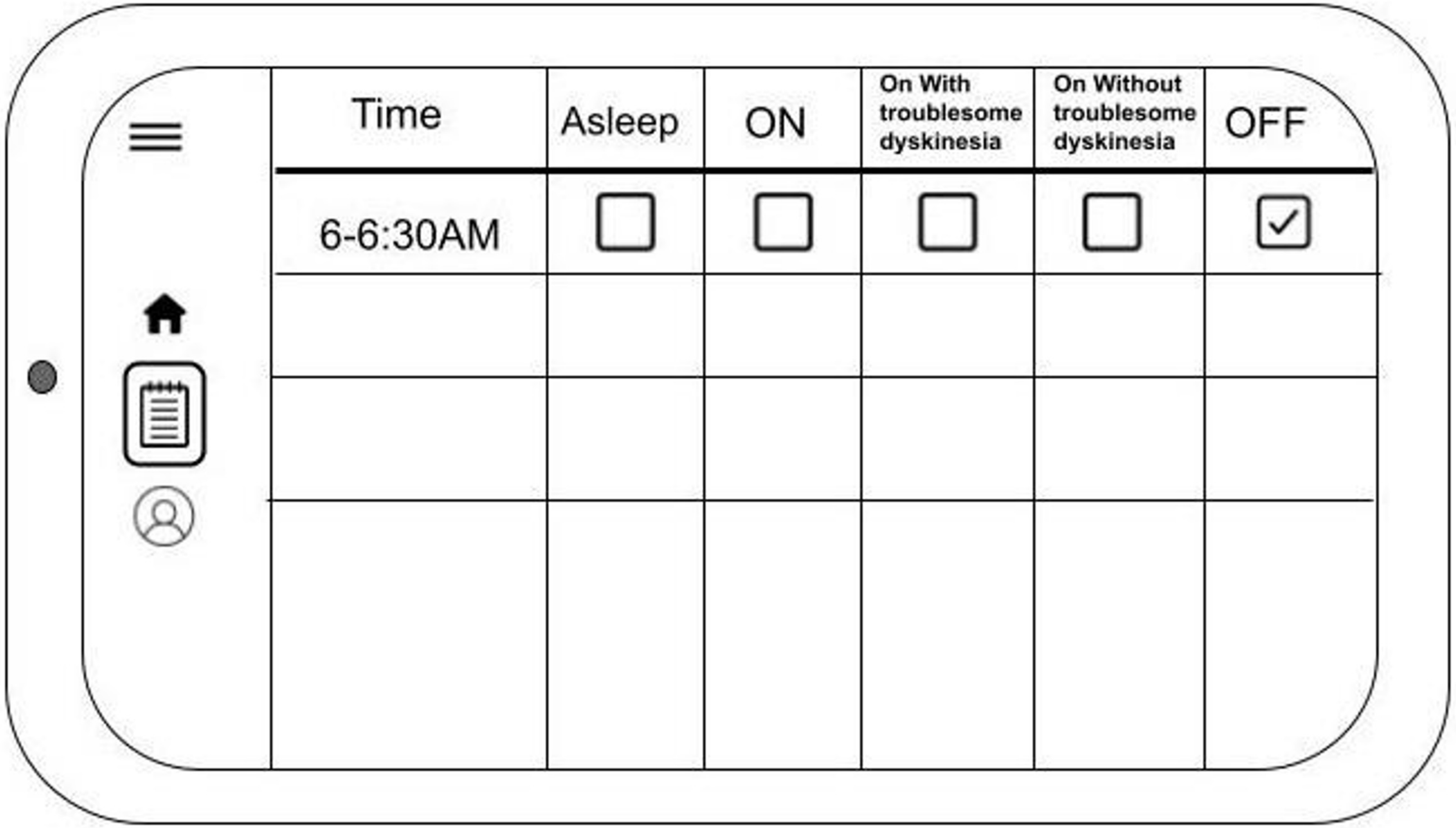
1. **Capture Sensor Data -** Accelerometer, Gyroscope, Heart rate, step counter.
2. **Implement PD Hauser Diary**

	ON	ON with dyskinesia	OFF	Asleep
06:00–06:30				×
06:30–07:00				×
07:00–07:30			×	
07:30–08:00			×	
08:00–08:30	×			
08:30–09:00	×			
09:00–09:30	×			
09:30–10:00	×			
10:00–10:30	×			
10:30–11:00			×	
11:00–11:30			×	
11:30–12:00			×	

App Design

The app captures the data related to hauser dairy.

A wireframe design of app -



App Design

- The sensor data collection is made by smartwatch app.
- The app collects sensor data of accelerometer, gyroscope, heart rate, step counter.
- The composite data is then to synced cloud every 10 minutes if the watch is worn.
- There also a feature on the app to indicate medication is taken.
- To optimize the battery usage data is collected at 50Hz frequency.

What is ML?

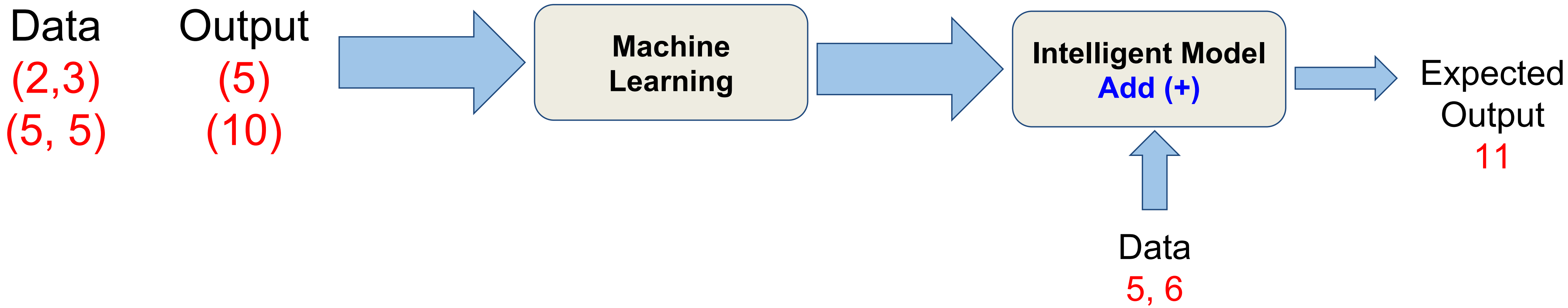
Traditional Programming

- Takes inputs and generates outputs based on the program
- Programs are fixed unless they are updated manually

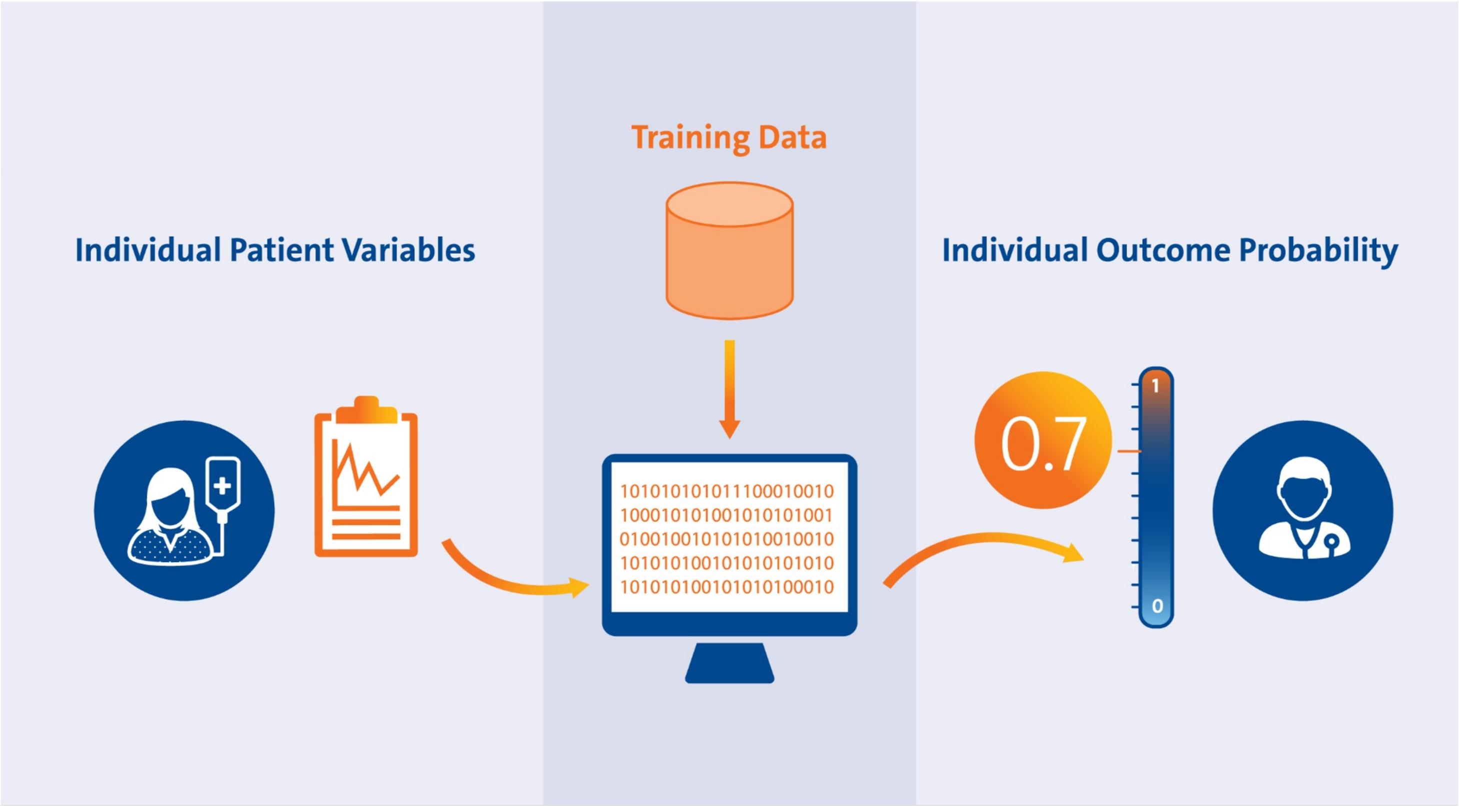
What is ML?

Machine Learning

- Takes data and expected output as input
- Learns the data patterns/representations without any type of explicit programming
- Continuously evolve into better models

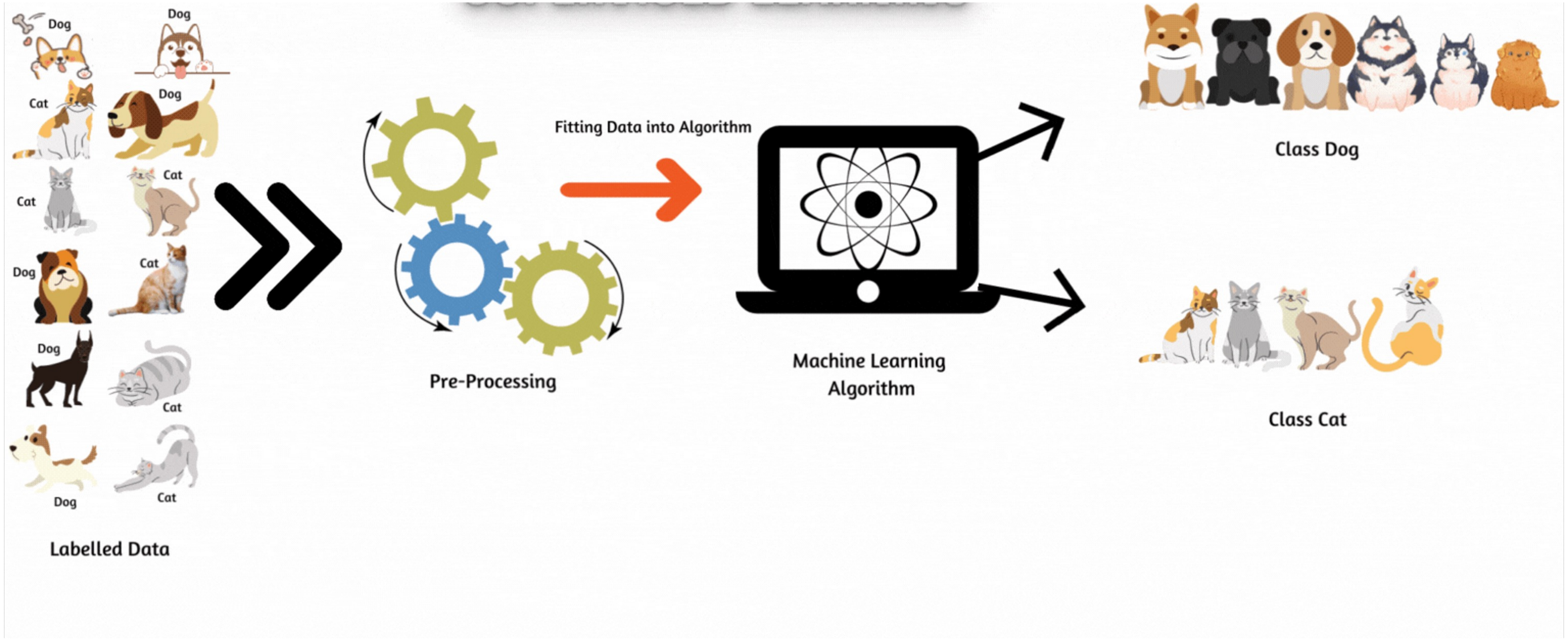


ML in Prediction



Supervised Learning

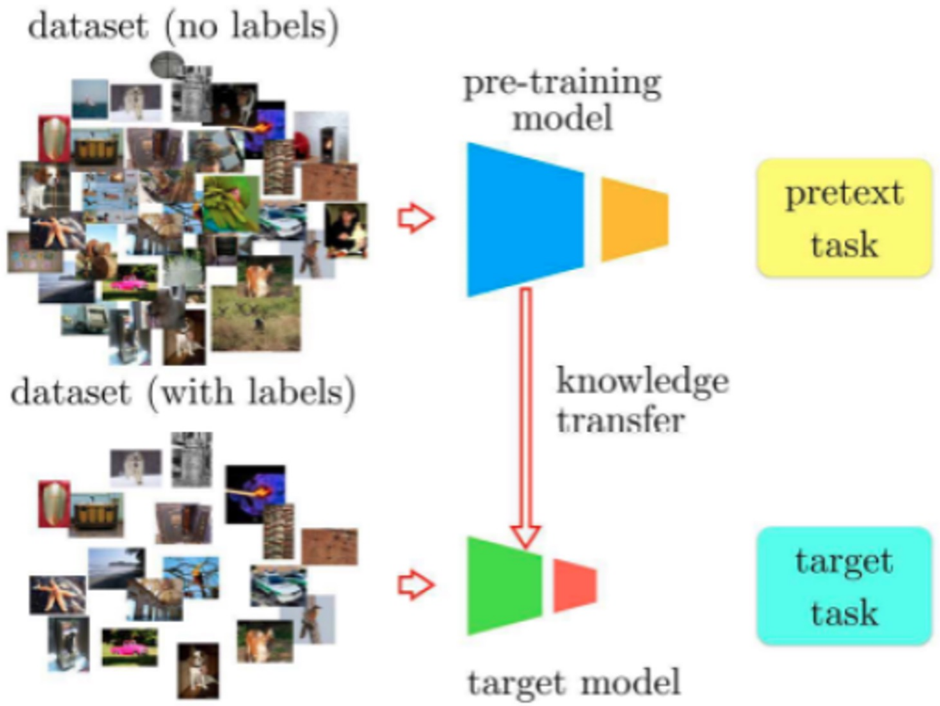
Train & Test both have labels (ground truth)



Self Supervised

Train the models in 2 steps

1. ***Pretraining:*** Uses unlabeled data and learns some interesting features/patterns
2. ***Finetune:***
   a. Uses the previous learned knowledge
   b. Retrains the learned knowledge using few labelled data to solve a specific problem



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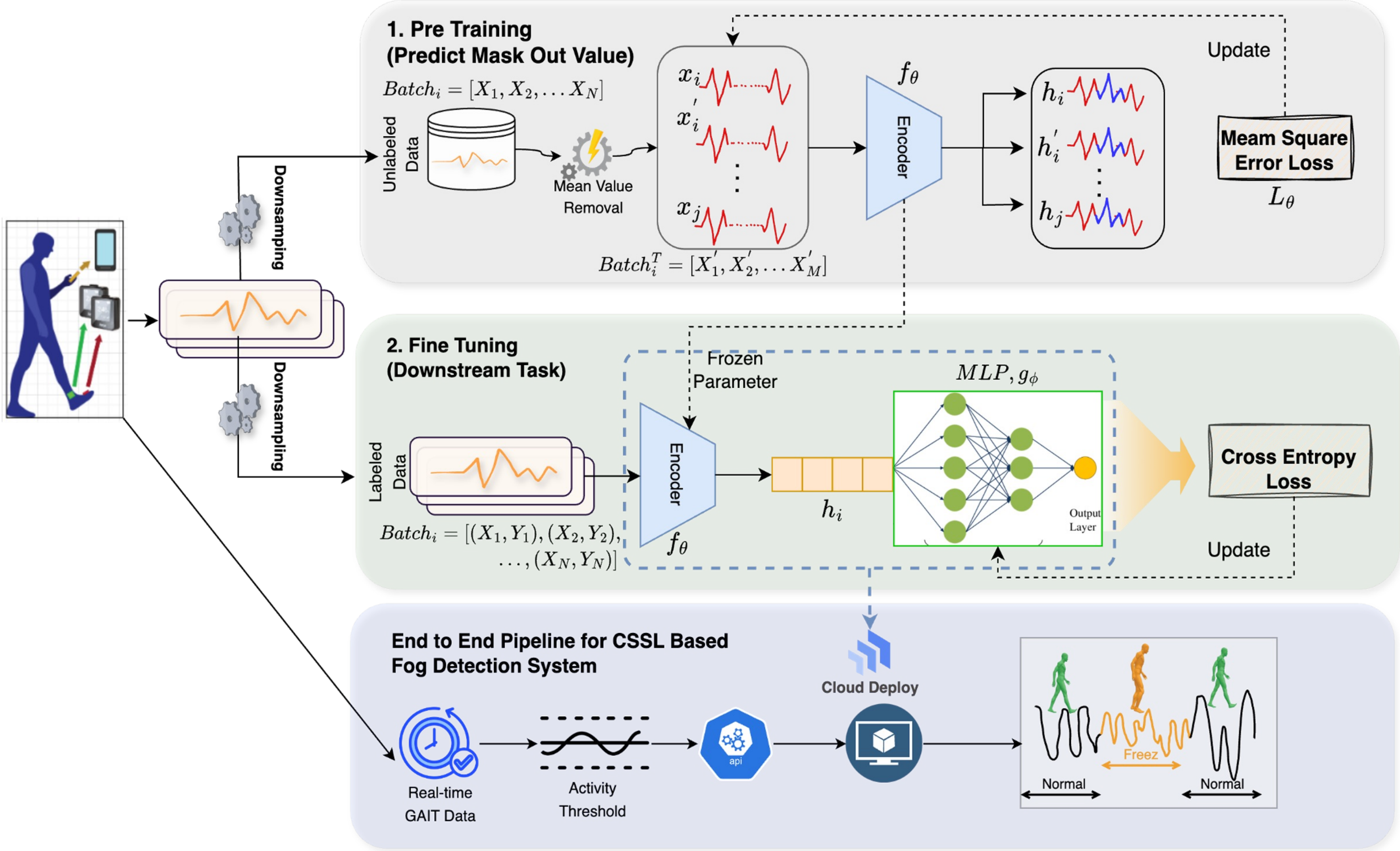
On Going PD Research

DEAP-ML: Data-Efficient, Adaptive, and Power-Aware Machine Learning for Parkinson's Long-Term Home Monitoring

DEAP-ML: Data-Efficient, Adaptive, and Power-Aware Machine Learning for Parkinson's Long-Term Monitoring

- A single IMU sensor → Reducing patient burdens
- Patient-independent Model
- Cost-effective opportunistic AI model
- Uncontrolled home environment for long time remote monitoring.
- Optimized for extended battery life



a. *Pretext Task:* Raw signals $X \in \mathbb{R}^{N \times T}$

Masked window, $\hat{X} = mask(X, m)$

Trained Pretext Model, f_θ

$$L_\theta = \frac{1}{N_m} \sum_{j=1}^{N_m} (\hat{x}_j - x_{p(j)})^2$$

b. *Down Stream Task:* MLP on top of pretext model

$$\hat{Y} = h_{\theta,\phi}(X) = g_\phi(f_\theta(X))$$

$$L_{ce}(\theta, \phi) = -\frac{1}{N} \sum_{i=1}^{N} [y_i \log(\hat{y}_i) + (1 - y_i) \log(1 - \hat{y}_i)]$$

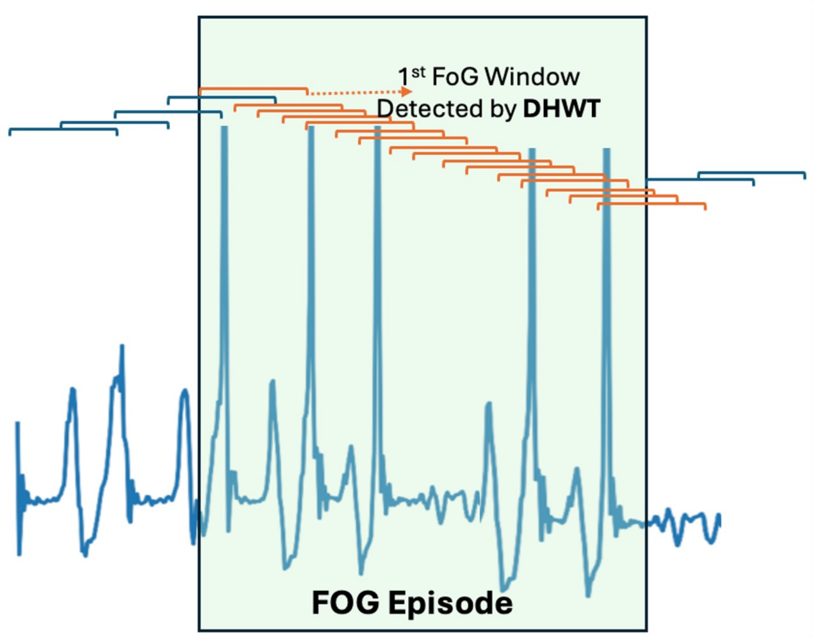
DEAP-ML: Data-Efficient, Adaptive, and Power-Aware Machine Learning for Parkinson's Long-Term Monitoring (Contd)

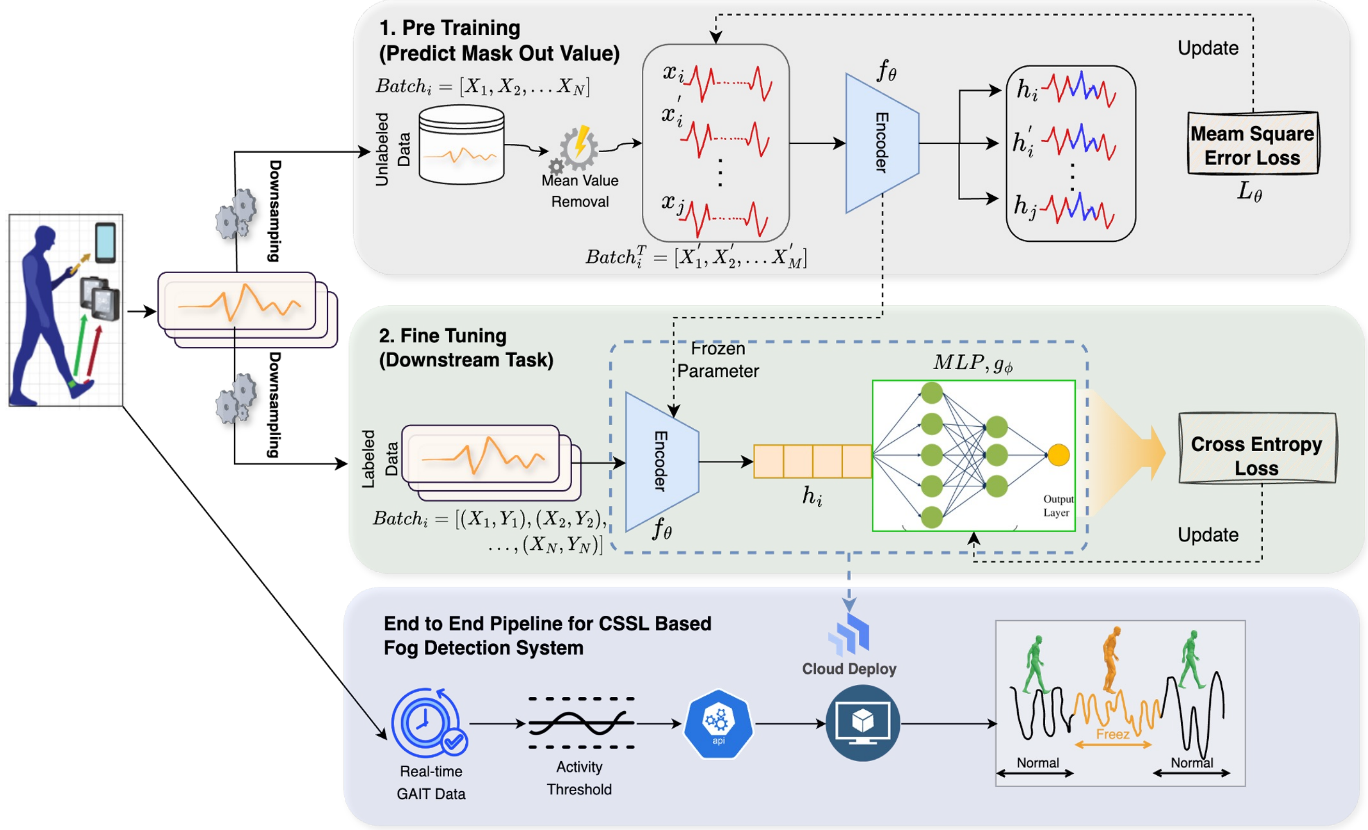
Differential Hopping Windowing Technique (DHWT)

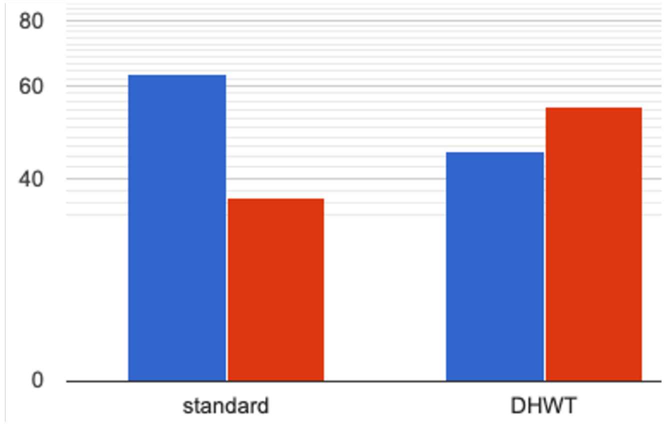
- Handle the imbalance dataset with low FoG samples

Minimal Preprocessing (Removing Mean-value from each window)

- Applied to **trainset only** to mimic real-world



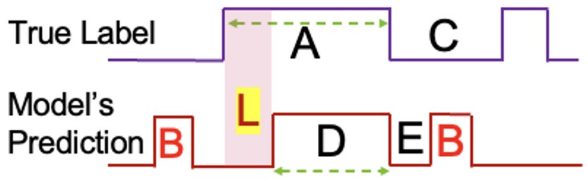




Results

- Using small amount data we got promising results
- Long FoG episodes are easily detectable

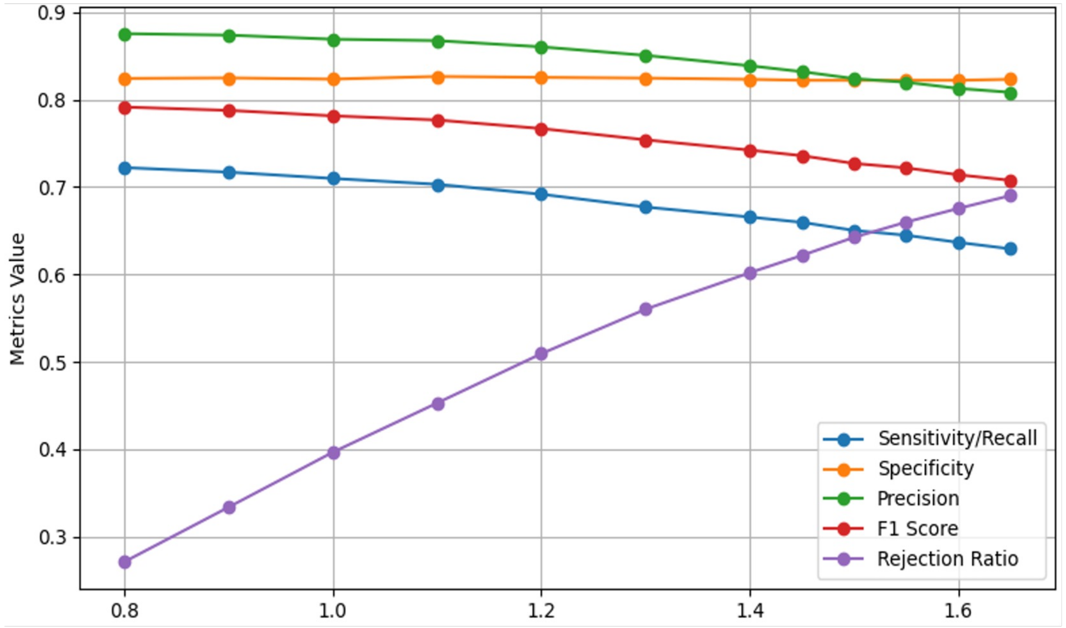
	Precision	F1	Accuracy	FoG Episodes	FoG windows, (Recall/ Sensitivity)
SSL	86.5%	79.7%	76.6%	**86.6%**	74.2
SUP	90.1%	86%	83.1%	**86.6%**	82

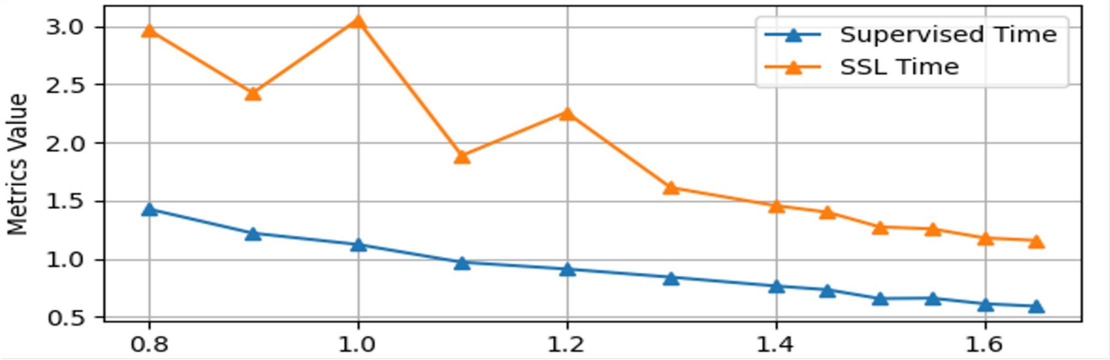


A: FoG Episode
L: Latency
B: False Positive
C: Normal Episode
D: Detected FoG Episode (TP)
E: Detected Normal Episode (TN)
**False alarm triggers just before/after a TFE

Episode Time (sec)	Avg Latency	Detected Episodes	Detected Windows (%)
< 5 sec	0.18s	88%	73%
6-12 sec	0.83s	86.21%	67%
>13 sec	2.35s	97.3%	82.4%

Results





$$magnitude, m = \sqrt{x^2 + y^2 + z^2}$$

- Set a magnitude Threshold (α) to discard the inactive windows.

If $m < \alpha$: discard the current window as it is inactive (not related to gait activities)

- It will extend the battery life
- Model will be lightweight → easy to deploy into a mobile wearable devices

Future Work

- **Suggest Effective Medication Plan**
  - Medication time
  - Medication dose

- **Assess PD Severity**
- **Detect atypical and typical PD**

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Thank You!

Lab Website: https://ghasemzadeh.com/