

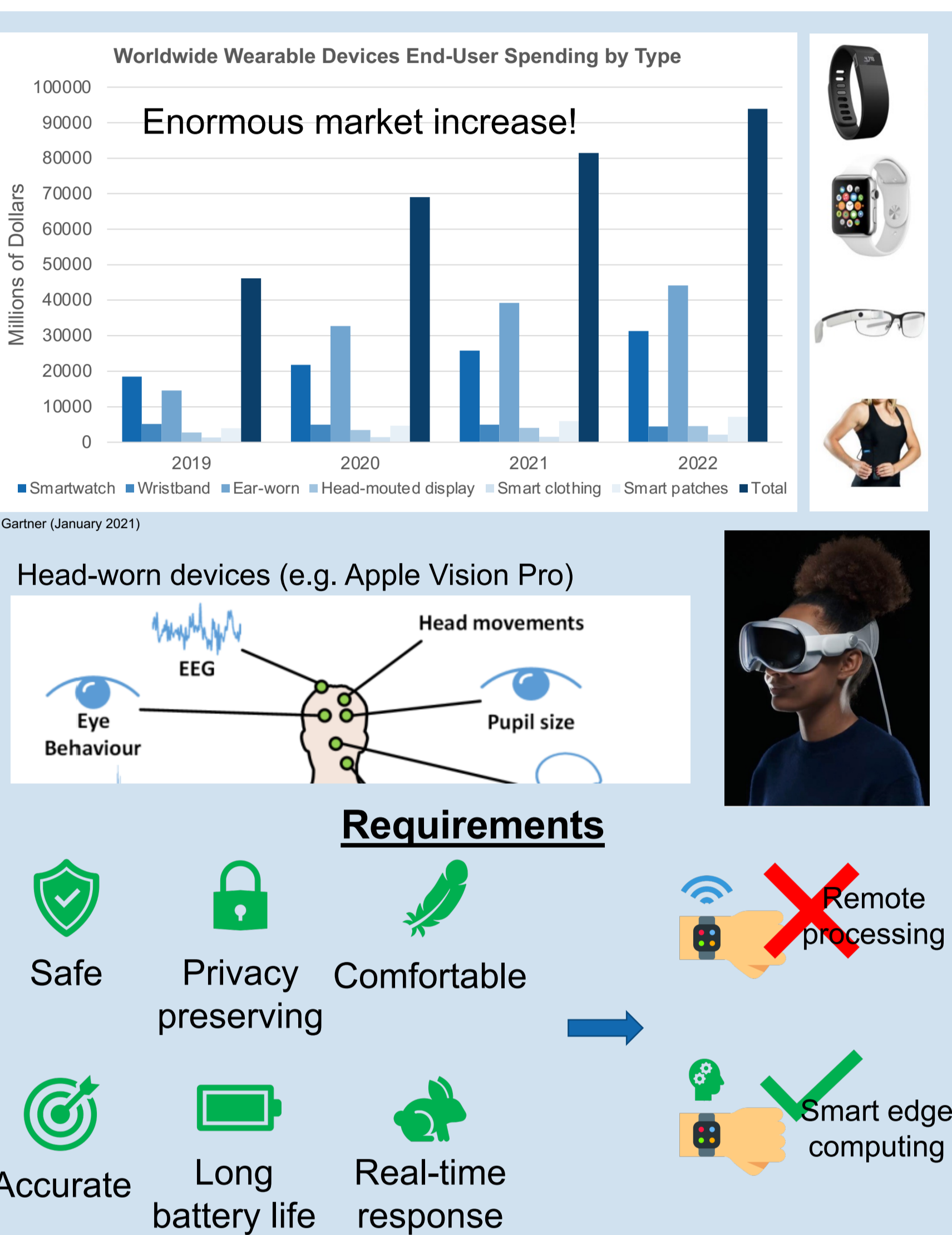
## Near-Sensor Analytics and Machine Learning for Long-Term Wearable Biomedical Systems

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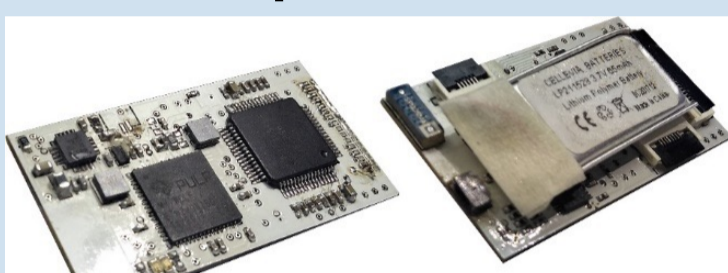
### Smart Wearable Devices



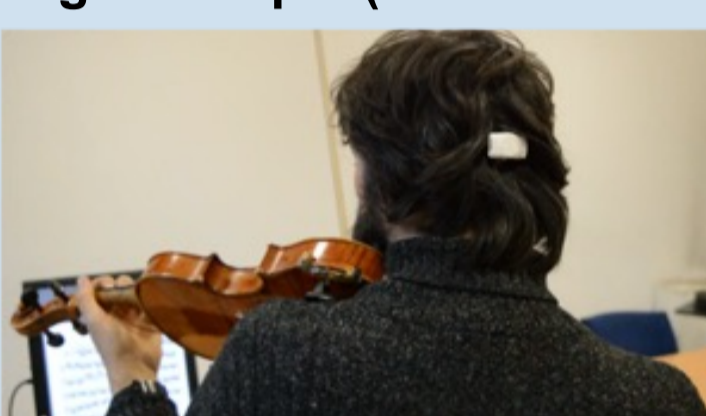
### Proposed Systems

#### BioWolf and BioGAP ExG Acquisition

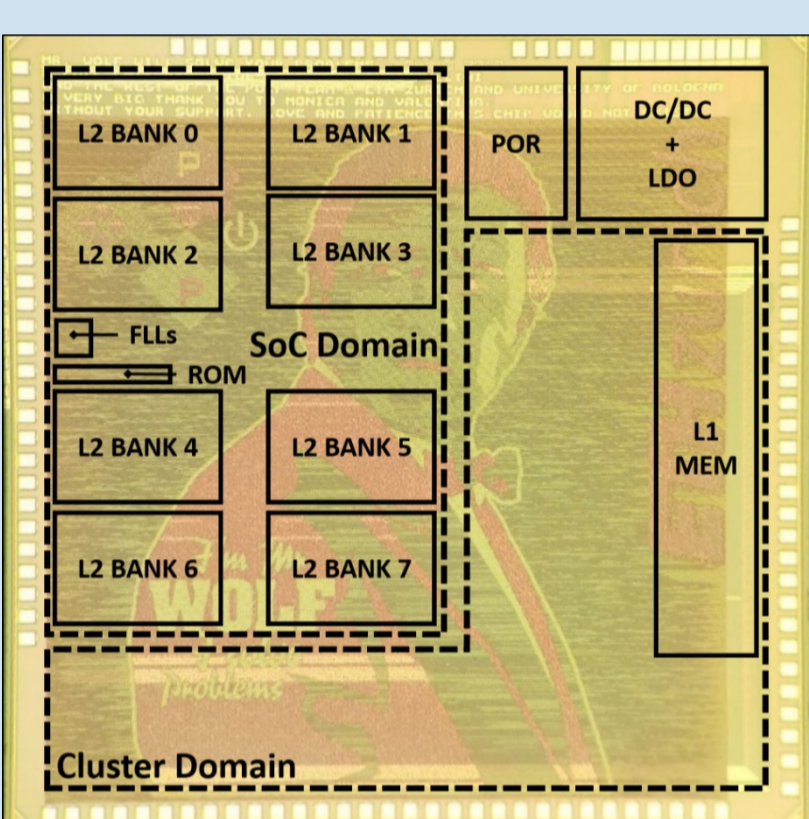
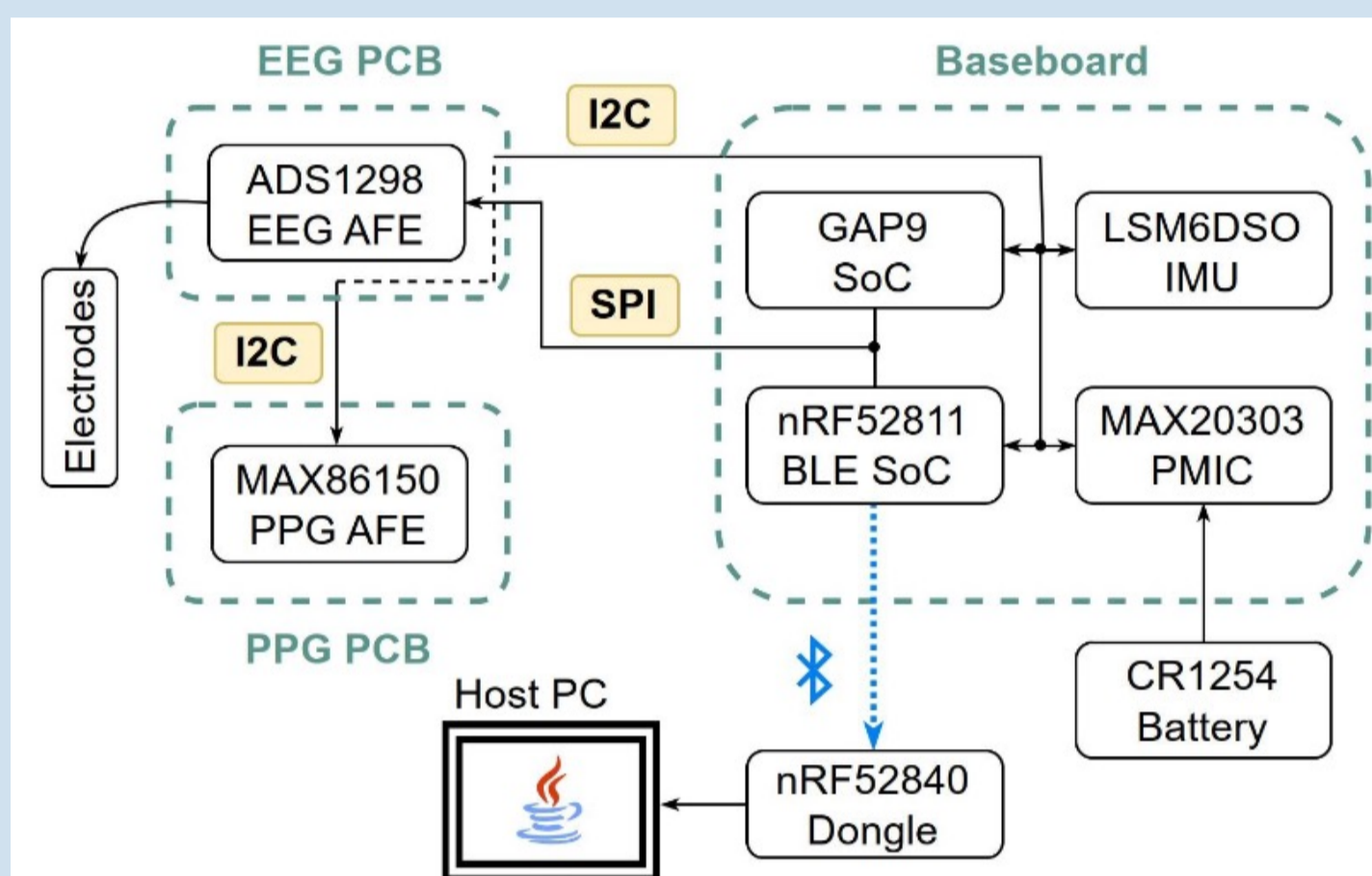
##### PCB implementation



##### Usage example (Patch-like encase)



- ADS1298**
- Up to 8 ExG channels
  - 24-bit of resolution
  - 0.5 to 32 – Ksps.
  - PGA up to 12x.
  - Dry active/Gel electrodes compatible.
- nRF52832**
- ARM Cortex-M4.
  - 64 MHz.
  - Bluetooth 5 capable.
  - NFC-A.
  - 512/64 KB Flash/RAM.



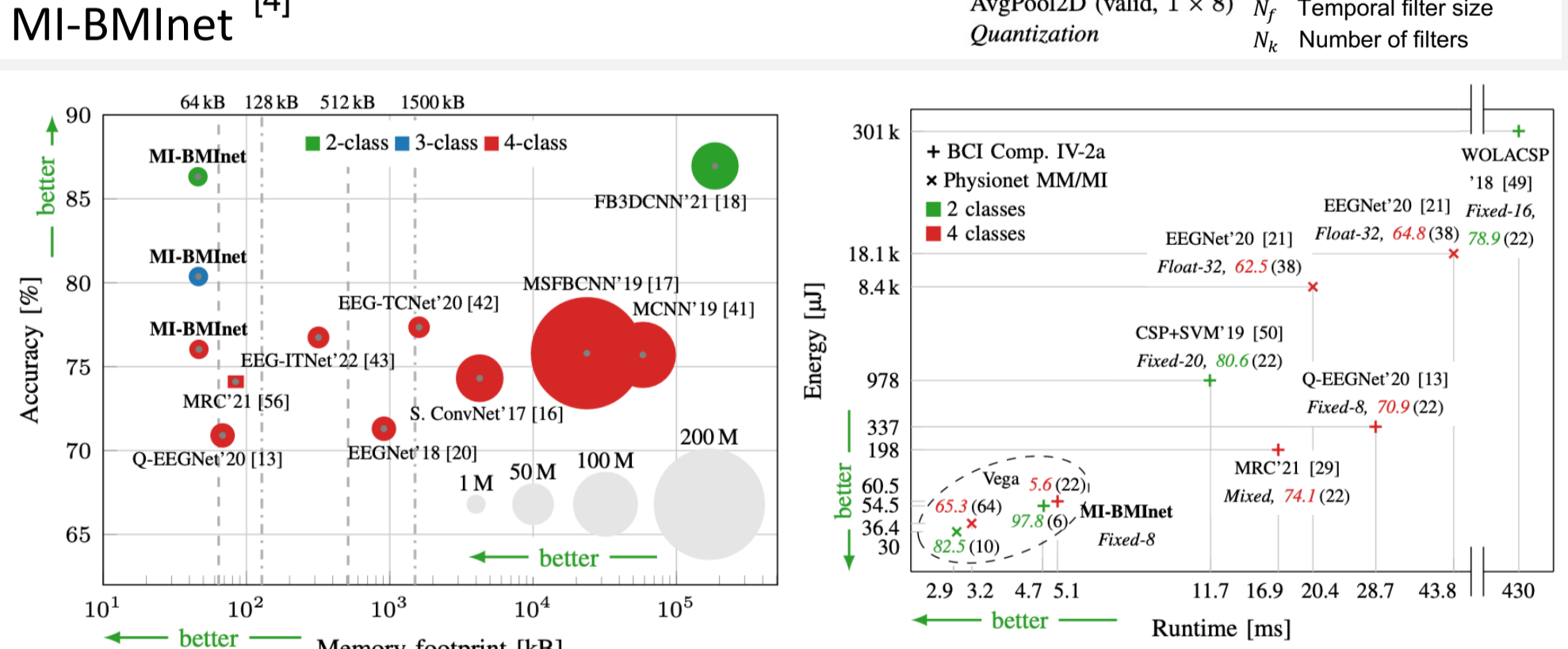
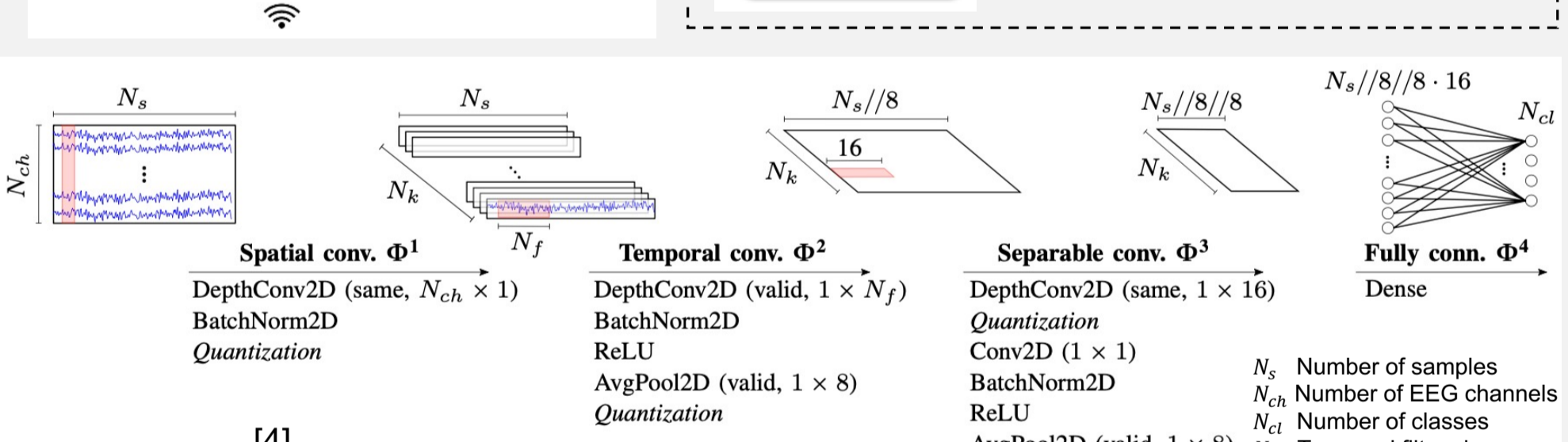
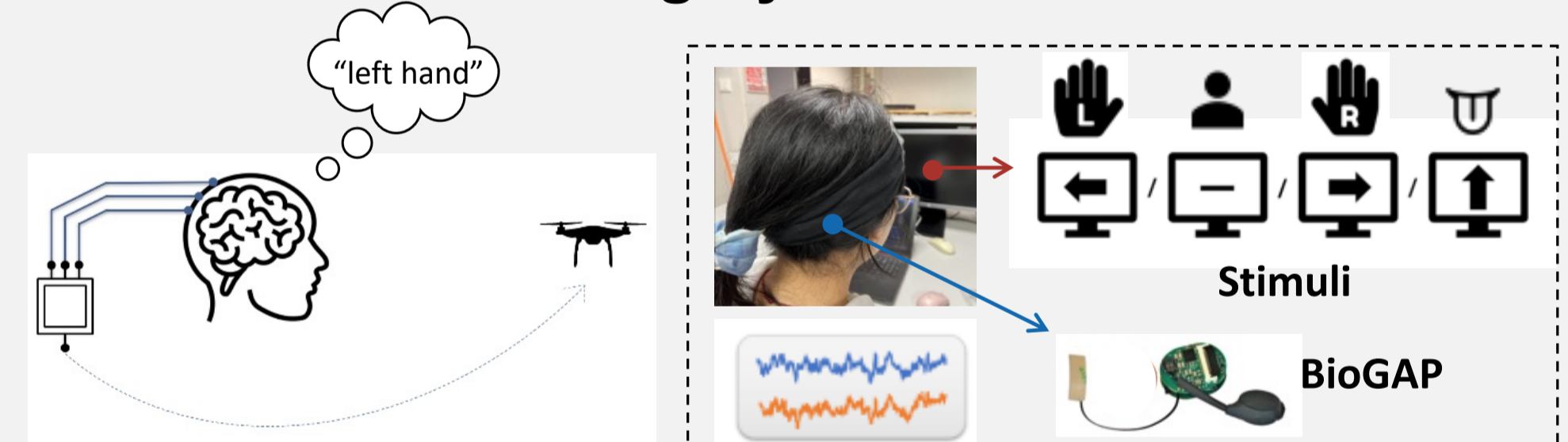
- PULP SoC**
- e.g. Mr. Wolf:
- 8 RISC-V cluster processors.
  - Voltage range (0.8V-1.1V).
  - 40nm LP CMOS.
  - 64kB/512kB L1/L2 memory.
- Peak Perf → 1GFLOP/s  
En.Eff. → 15MMAC/s/mW and 9MFMAC/s/mW



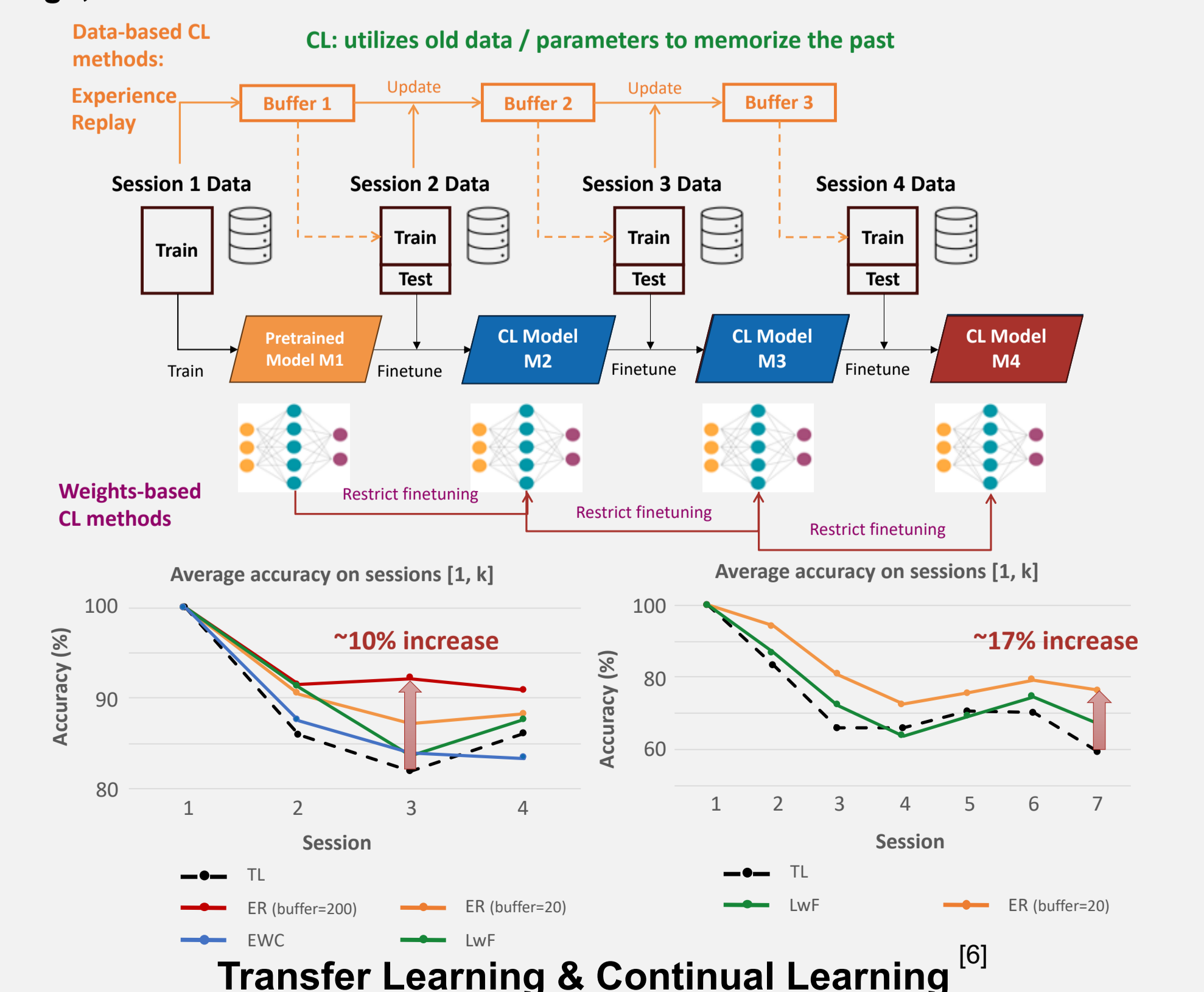
Miniaturized and non-stigmatizing!

### Developed Applications

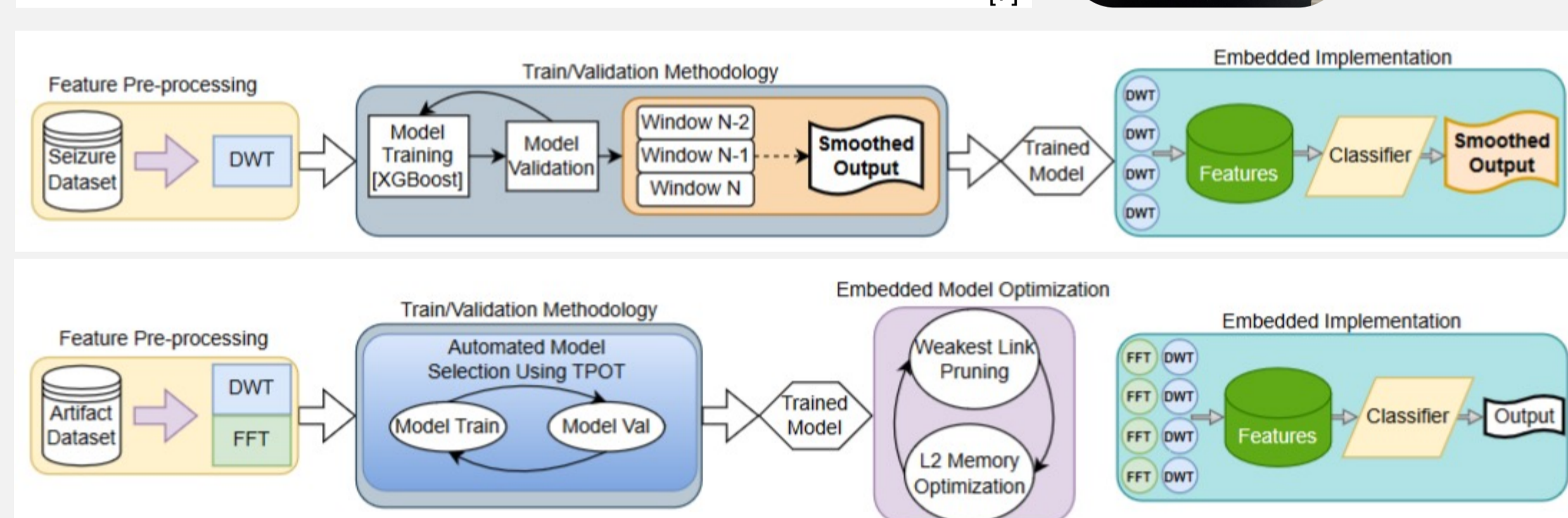
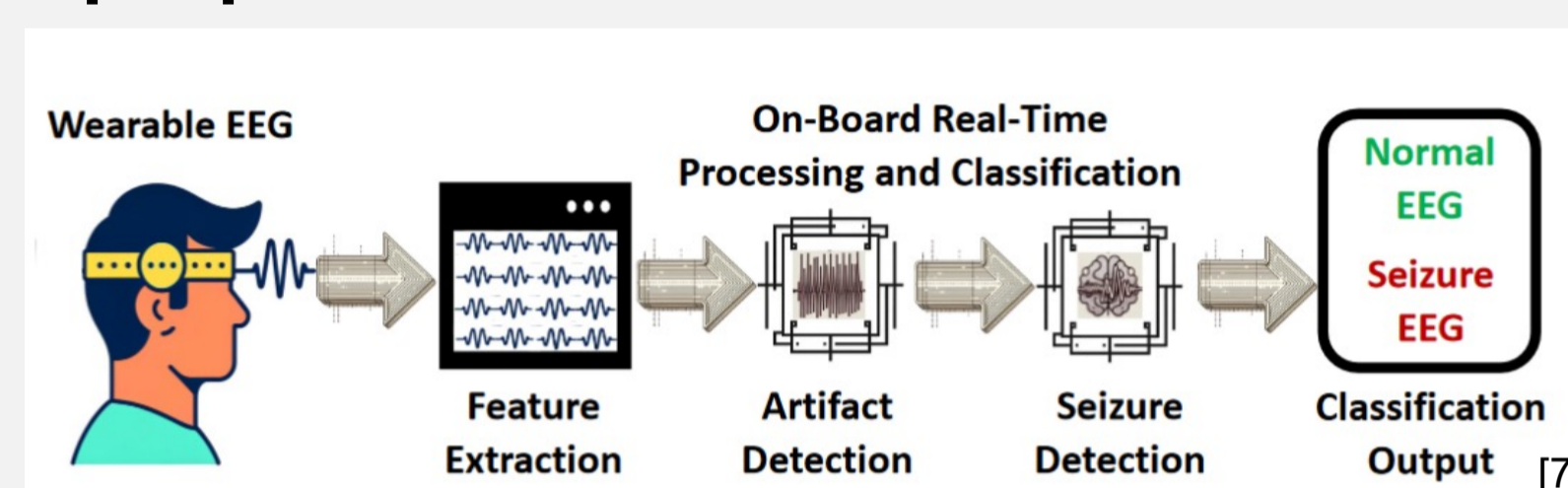
#### Motor Movement/Imagery Brain-Machine Interfaces



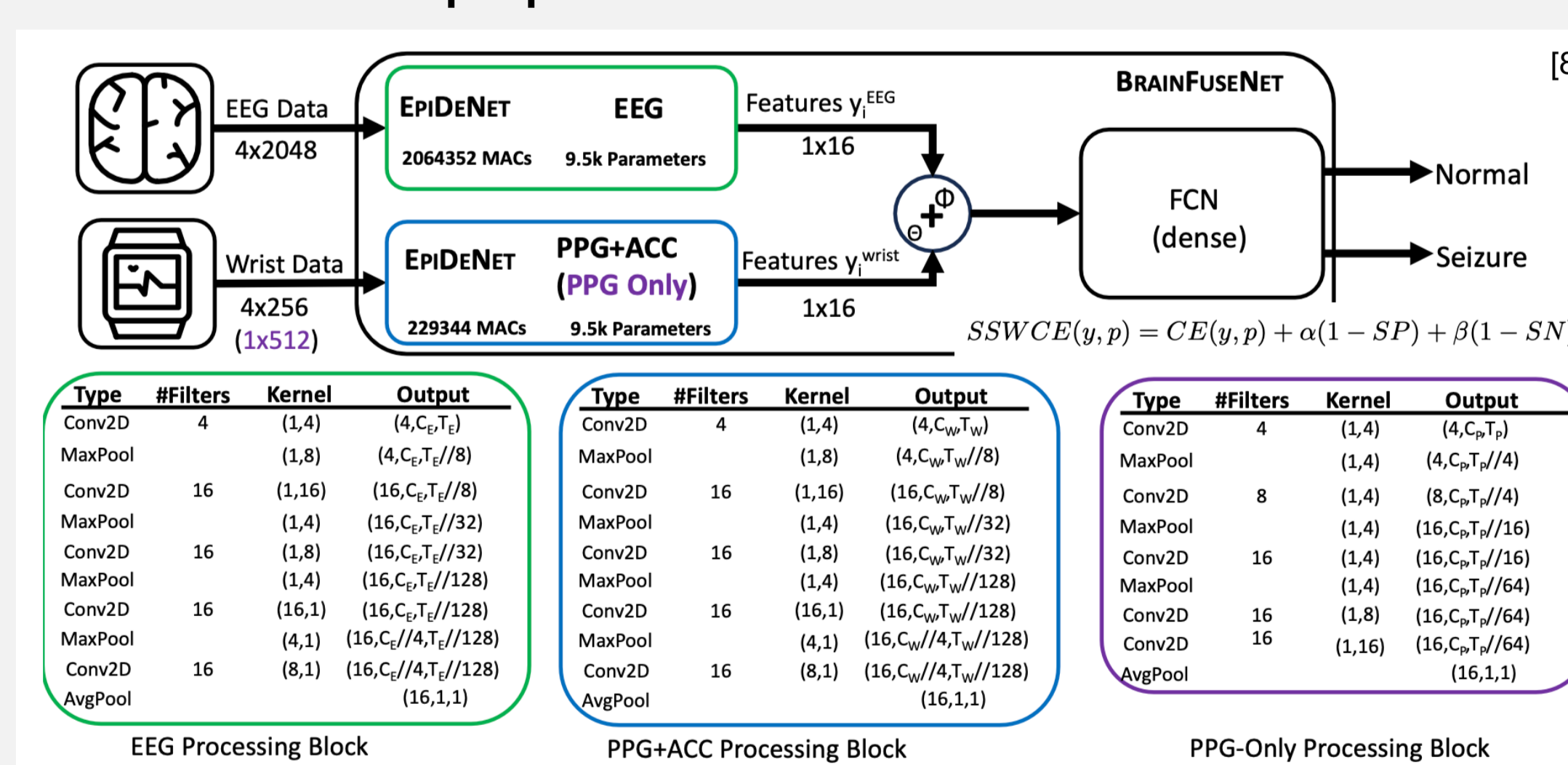
86.32% 2-class accuracy on BCI Competition IV-2a dataset. Memory requirement: <50kB; Energy consumption: <60μJ/inference on PULP Vega; Runtime: <5ms/inference.



#### Epileptic seizures detection

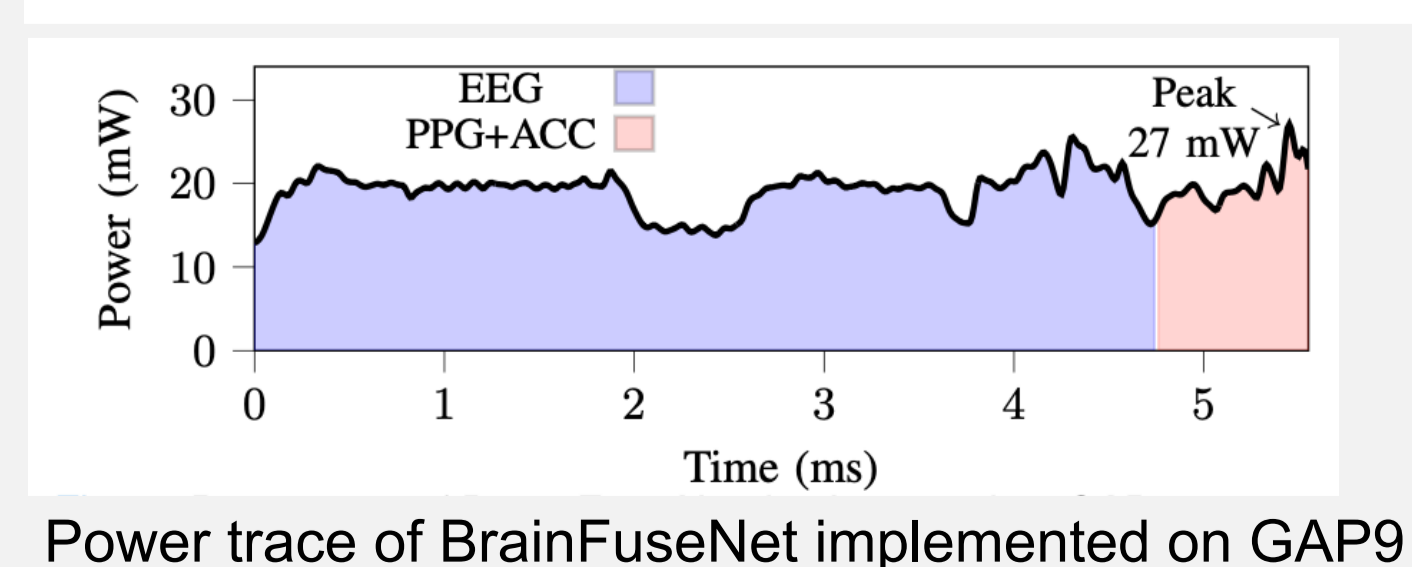


#### Sensor fusion for epileptic seizures detection

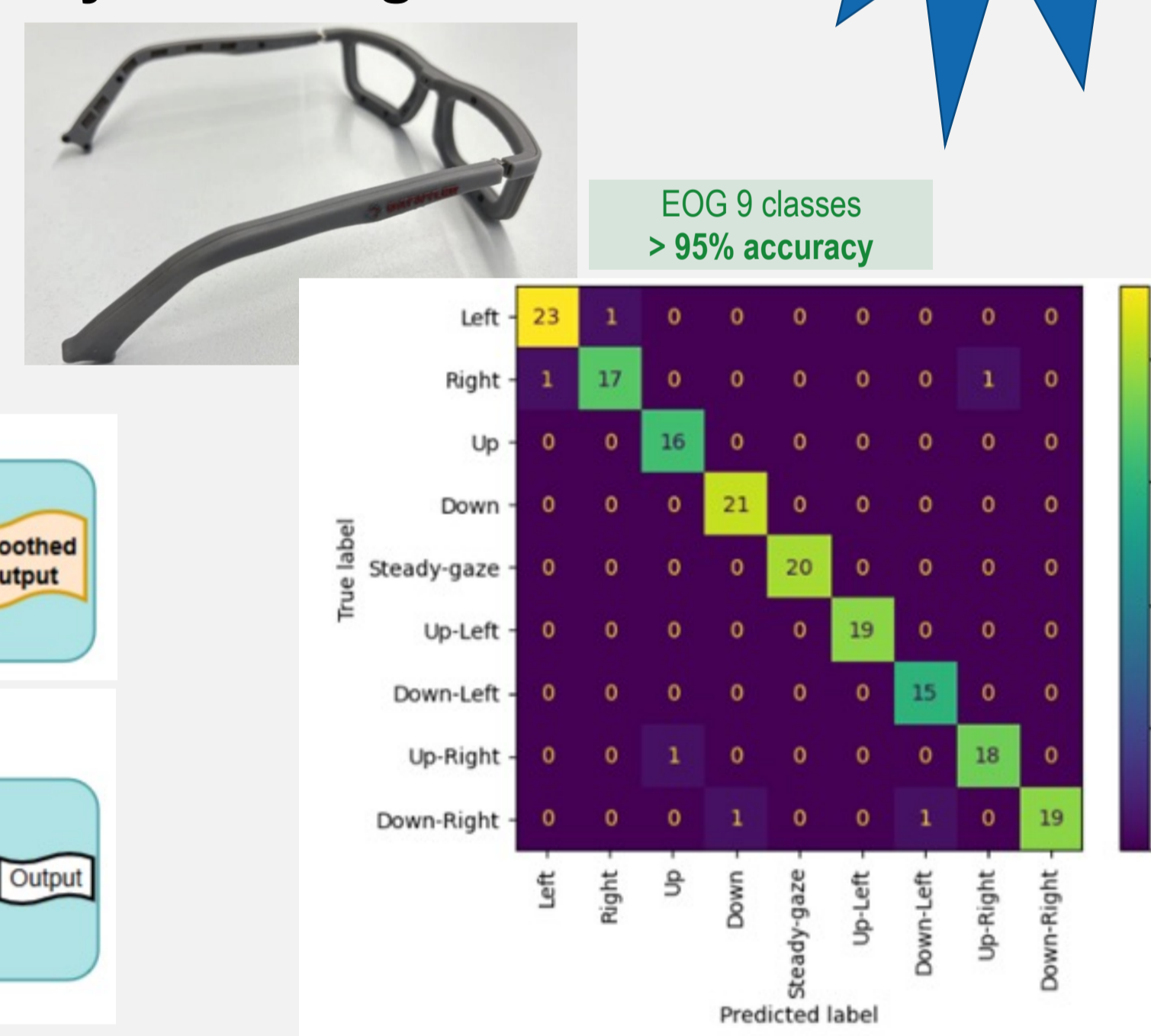


#### Seizure detection results on the PEDESITE dataset

Patient	EEG CE			EEG (smooth) SSWCE			EEG+PPG (smooth) SSWCE			EEG+PPG+ACC (smooth) SSWCE		
	Sens [%]	Spec [%]	FP/h	Sens [%]	Spec [%]	FP/h	Sens [%]	Spec [%]	FP/h	Sens [%]	Spec [%]	FP/h
P1	9.70	99.52	2.16	25.20	99.62	1.71	22.90	99.76	1.08	-	99.98	-
P2	57.00	100	0	59.44	100	0	59.10	100	0	46.31	99.98	0.11
P3	68.20	99.48	2.34	65.45	99.67	1.48	69.95	99.56	1.98	60.07	99.95	0.24
P4	73.40	99.72	1.26	77.86	99.78	0.99	82.29	99.82	0.81	77.95	99.85	0.68
P5	91.10	99.82	0.81	92.50	100	0	91.24	100	0	91.06	100	0
P6	48.70	96.90	14.0	43.49	99.36	2.88	41.81	99.50	2.15	46.03	100	0
<b>Average</b>	<b>58.02</b>	<b>99.24</b>	<b>3.43</b>	<b>60.66</b>	<b>99.74</b>	<b>1.18</b>	<b>61.22</b>	<b>99.77</b>	<b>1.00</b>	<b>64.28</b>	<b>99.96</b>	<b>0.21</b>



#### Eye Tracking



### Acknowledgements

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#### Demo videos



<https://efci.ethz.ch/Media/project-videos--demos.html>