Department of Biomedical Engineering

VI Semester

CBM 370 - Wearable Devices

Unit- 5 APPLICATIONS OF WEARABLE SYSTEMS

5.5 Neural Recording

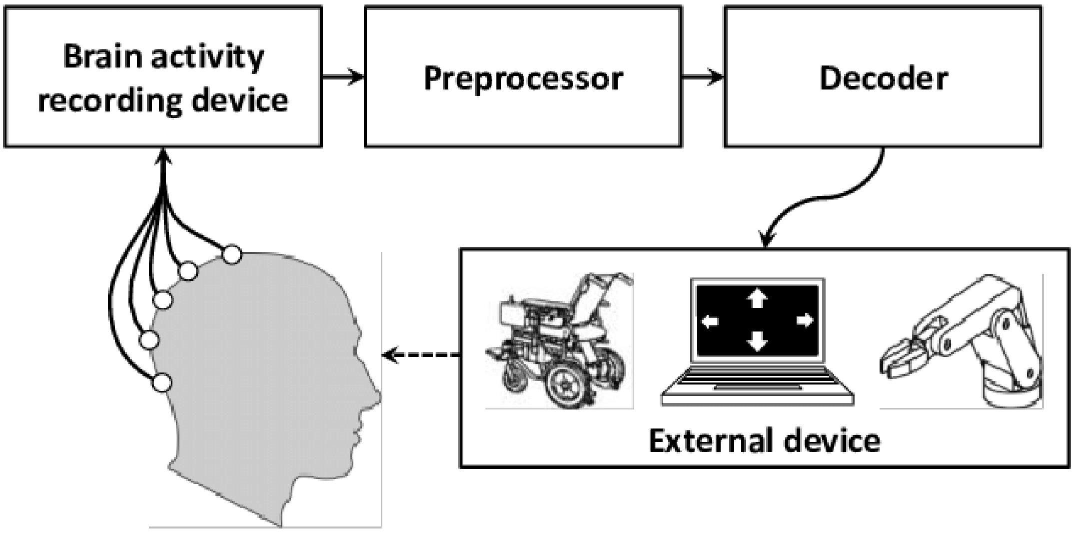
Wearable devices have become increasingly important in neuroscience and neurotechnology, particularly for neural recordings. Their non-invasive nature and ability to be used in real-world environments make them highly valuable for research, clinical, and consumer applications. Here are some applications of wearable devices in neural recordings:

1. Neurological Disease Diagnosis and Management

- **Epilepsy**: Wearable EEG devices detect abnormal brain activity and seizure events, aiding in diagnosis and treatment optimization.
- **Parkinson's Disease**: EEG-based wearables combined with AI can remotely detect motor and non-motor symptoms, supporting early diagnosis before neurodegeneration progresses.
- **Alzheimer's and Dementia**: Neural recording wearables track cognitive decline, providing valuable insights into disease progression.

2. Brain-Computer Interfaces (BCIs):

- BCIs enable direct communication between the brain and external devices, helping individuals with paralysis or motor impairments control prosthetics or computers. For example:
- The Neuro-stack records single-neuron activity during dynamic tasks like walking, offering insights into real-world brain function.
- Non-invasive neural interfaces developed by Carnegie Mellon University combine recording and stimulation capabilities for next-generation BCIs.



[*Figure:* Anderson Mora-Cortes, et.al,2014]

***Figure**: Brain – Computer Interface*

- ❖ Sensors (like **EEG electrodes**) placed on the scalp record neural signals. These signals reflect brain activity such as motor intentions, visual attention, or imagined movements.
- ❖ **Wearable EEG headsets** are common for non-invasive BCIs. Raw brain signals are noisy, so they go through **preprocessing**.
- ❖ The cleaned signals are sent to a **machine learning model or algorithm** to decode the user's intention.
- ❖ The decoded brain signals are used to control external devices, such as: **Wheelchairs** (mobility assistance), **Computer interfaces** (communication, cursor control) and **Robotic arms** (for manipulation, prosthetics).
- ❖ Some systems may include **feedback** from the device back to the brain (via visual or tactile cues), helping users improve control through neurofeedback or reinforcement learning.

3. <u>Mental Health Applications:</u>

- ❖ Wearables measure brain activity to monitor and manage conditions such as depression, anxiety, ADHD, and PTSD. Neurofeedback systems provide real-time feedback to help patients regulate their mental states.

- Transcranial direct current stimulation (tDCS) devices are used to treat inattention symptoms in ADHD patients and modulate eating behaviors in individuals with disordered eating.

4. Sleep Monitoring:

- Wearable EEG headsets analyze sleep stages and detect disorders like insomnia or sleep apnea, helping improve sleep hygiene and overall health.

5. Cognitive Performance Enhancement:

- Neurofeedback training using wearable EEGs enhances focus, memory, and learning capabilities. Applications include optimizing performance in athletes, students, or professionals under stress.

6. Rehabilitation:

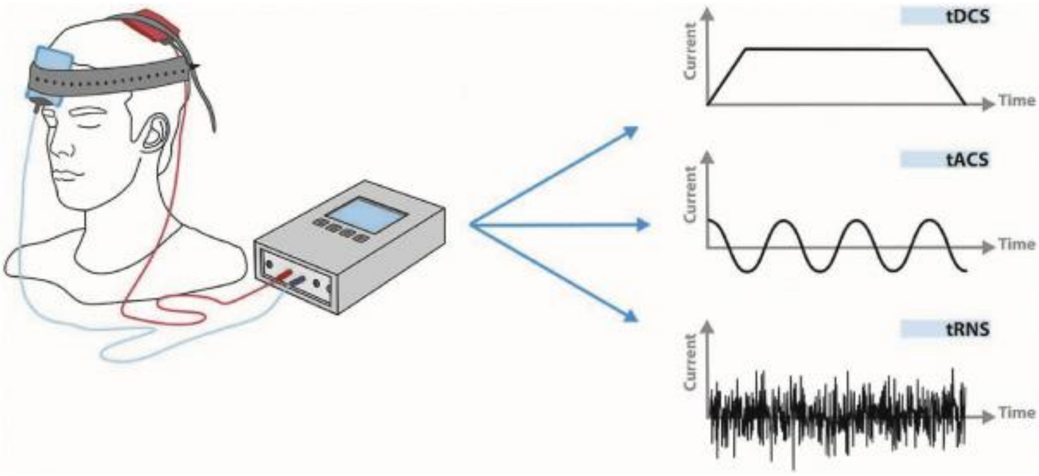
- Neural recording wearables assist in stroke recovery by monitoring brain activity during therapy sessions. They provide insights into neural plasticity and recovery progress.
- Devices combining sensing and stimulation capabilities can be used for precise therapeutic interventions in neurodegenerative diseases like epilepsy, Alzheimer's, and Parkinson's.

7. Research in Natural Settings:

- Portable EEG systems enable long-term studies of brain function outside laboratory settings. For example:
- The Neuro-stack allows researchers to study single-neuron activity during real-world tasks like walking or interacting with the environment.
- "Fitbit for the Brain" uses silicon/silver nanowire sensors embedded into headbands or helmets for unobtrusive extended wear.

8. Non-Invasive Therapeutics:

- Emerging wearable systems integrate sensing with stimulation (e.g., tDCS or transcranial electrical stimulation) to treat neurological conditions non-invasively.



- A person is wearing a headband-type neural stimulator with electrodes placed on the scalp. A stimulation device delivers electrical currents in different patterns to modulate brain activity. Three different waveforms are shown on the right side, representing:
  1. tDCS (Transcranial Direct Current Stimulation)
  2. tACS (Transcranial Alternating Current Stimulation)
  3. tRNS (Transcranial Random Noise Stimulation)

Challenges:

- **Signal Quality**: Noise reduction and motion artifact handling remain critical issues.
- **Data Privacy**: Protecting sensitive neural data is essential to address ethical concerns.
- **Cost and Accessibility**: High costs limit widespread adoption; affordable models are needed.

Wearable neural recording systems are advancing neuroscience by enabling continuous monitoring of brain activity in real-world environments while paving the way for innovative diagnostic tools and therapeutic interventions.

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