H.A.P.P.I Hat: Speedy E.E.G

Human Augmented Perception Processing Interface

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daqscribe — The Ethernet Recorder Company

Motivation

Problem: The current EEG devices are often uncomfortable for prolonged use, and are limited to clinical use environments and complex setups
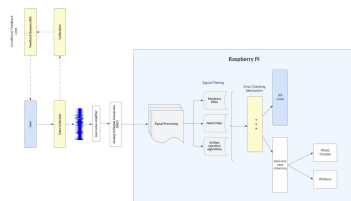
Our Goal: The team aimed to design a comfortable, user-based EEG system that allows for data collection and is adjustable for any user.

Solution: The team built an EEG (Electroencephalogram) a device capable of being worn for 6 hours at a time and storing 24 hours of continuous usable data. The system is adjustable and usable to all head and hair types
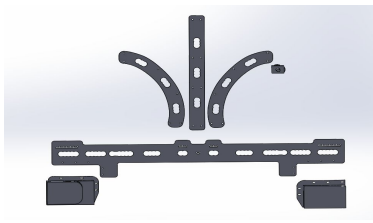
Diagrams

Data Flow:
The chart depicts the data flow process for the system

2D Assembly of the Mechanical System:

References
1. Overview of MEG/EEG analysis with MNE-Python#. *Overview of MEG/EEG analysis with MNE-Python - MNE 1.9.0 documentation*, (available at https://mne.tools/stable/auto_tutorials/intro/10_overview.html).
2. Neuroelectrics, EEG Signal Processing for Dummies. *Neuroelectrics* (2024), (available at https://www.neuroelectrics.com/blog/eeg-eeg-signal-processing-for-dummies).

Design Process

Design Highlights:
The system is adjustable for any head and hair type, with data streaming, that can be collected for a full day
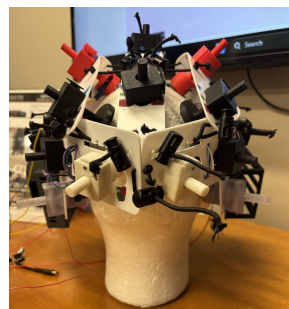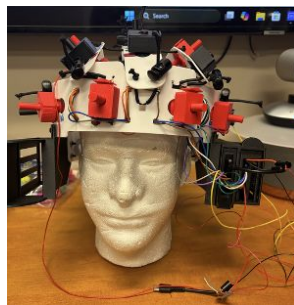
Testing:
- Sampling: brainwaves are captured on the Cyton board with a Daisy module at 250Hz and 24-bit resolution
- EEG data stored on SD card at about 500 MB/day
- Battery systems comply with regulatory policies and are designed for balance and comfort on the headband system
- Sensor mounts are adjustable and can move along the track system, which aligns with 10-20 standard

Mechanical System:
- Electrode along the 10-20 electrode placement systems, with adjustable mounts corresponding to headband placement
- Bungee system between tracks for overall head size adjustment

Performance

Positive:
- Battery operates over 20 hours
- Sampling rate meets design requirements of 250Hz with 8 channels
- Track system supports the electrode placement per the 10-20 standard
- Suitable for all head and hair types
- Our dry-based electrode system takes 5 minutes to set up, whereas the wet one takes 2 hours

Negative:
- The data collected is not consistent
- The impedance level is high for each channel
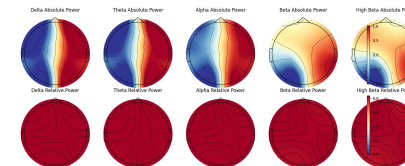
Recommendations for Future Work

- Explore the wireless data streaming and incorporate a mobile app for a better user interface
- Incorporate AI for better data analysis & preprocessing
- Improve wire management for components
- Decrease the system's weight with lighter electrical components

Impacts of the project
- Capturing high-quality signals at home saves time and resources to diagnose and monitor conditions
- The system will expand the use of EEG systems in remote areas
- Longer collection of data and increased EEG data itself will lead advances in understanding the brain
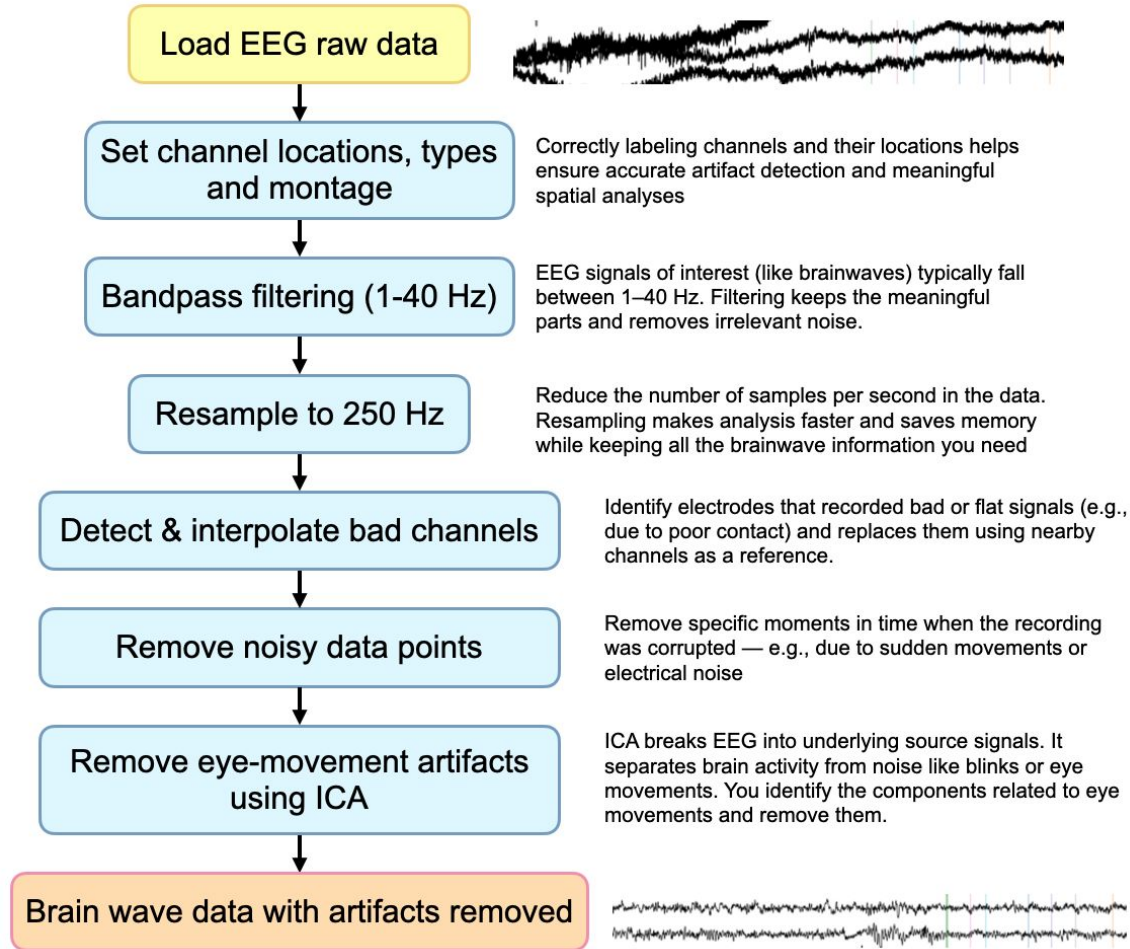
Acknowledgements

Data Preprocessing

Load EEG raw data

Set channel locations, types and montage — Correctly labeling channels and their locations helps ensure accurate artifact detection and meaningful spatial analyses

Bandpass filtering (1-40 Hz) — EEG signals of interest (like brainwaves) typically fall between 1–40 Hz. Filtering keeps the meaningful parts and removes irrelevant noise.

Resample to 250 Hz — Reduce the number of samples per second in the data. Resampling makes analysis faster and saves memory while keeping all the brainwave information you need

Detect & interpolate bad channels — Identify electrodes that recorded bad or flat signals (e.g., due to poor contact) and replaces them using nearby channels as a reference.

Remove noisy data points — Remove specific moments in time when the recording was corrupted — e.g., due to sudden movements or electrical noise

Remove eye-movement artifacts using ICA — ICA breaks EEG into underlying source signals. It separates brain activity from noise like blinks or eye movements. You identify the components related to eye movements and remove them.

Brain wave data with artifacts removed

Data Analytics

Brain wave data with artifacts removed

Power Spectrum Analysis

- Goal: Analyze **brainwave power** (Delta, Theta, Alpha, Beta, etc.)

- How? Compute **Power Spectral Density** (PSD) – a measure of how strong different brainwave frequencies are, per channel.

  ‣ Create:
    - **Absolute power** (total strength of the band)
    - Z-scored power (standardized)
    - **Relative power** (proportion of total power)

- Plot scalp maps to visualize **how power is distributed across the head** — for both absolute and relative power.

Connectivity Analysis

- Goal: Find **how brain areas are functionally connected**

- How?
  - Compute **coherence**: how similar signals are between channels.
  - Compute **PLI (Phase Lag Index)**: how consistently one signal leads/lags another in phase.

- Plot **brain connectivity networks**