In Which I Attempt To Explain Everything

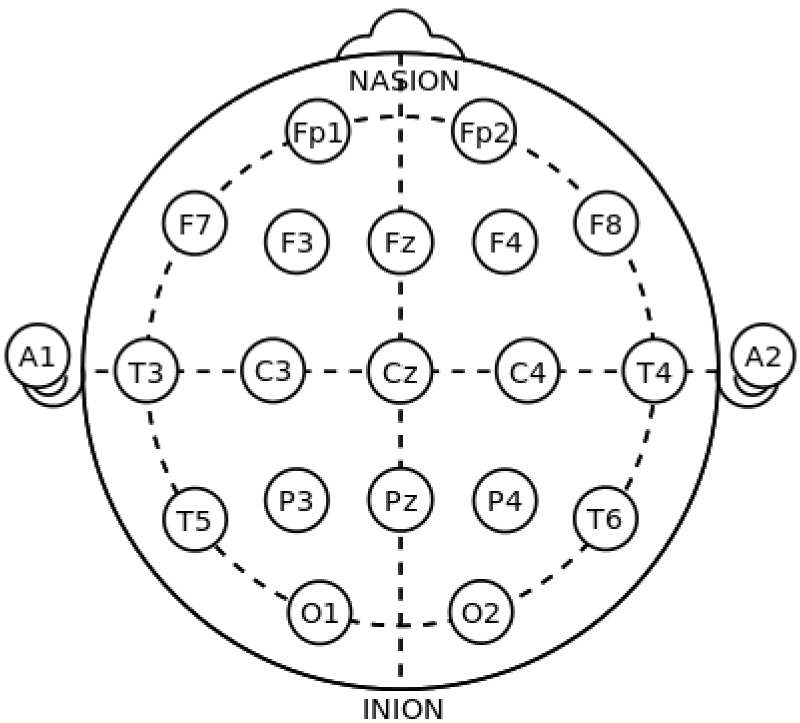
(Will be improved over the coming days.)

What exactly are we planning to do? During week one, we'll be designing a board similar to OpenBCI's Cyton board among other initiatives out there, like hackEEG and piEEG, that will allow us to read brain waves using EEG. The significance of this board is that it will be significantly more financially viable compared to the rest of the market. We'll order this board through JLCPCB (with parts sourced from LCSC and DigiKey) and assemble it during the second week, which will be more focused on software: getting visual readings; designing a programmable API wrapper around the board; and finally using the board with electrodes we already own to play a game, e.g. Flappy Bird.

What is EEG? EEG is short for electroencephalography, and it's a method that can be used to record electrical activity in the brain from a bird-eye's perspective. A better analogy, perhaps, is to compare it to "the aggregate flow of activity on the Internet, where you can't read any individual email but can see macro traffic patterns" (Sapien Labs).

There are various applications of this, but the one that stands out to me the most is using EEG to measure and improve focus. From ACX: "In 2022, a team in Cambridge found that experimental subjects learned faster stimuli… when presented at their brain's unique alpha rhythm. The scientists monitored their brain waves to figure out exactly what each subject's alpha rhythm was (usually a pattern of flashes about a dozen times per second), then presented a flashing pattern that hit the trough of each alpha wave, then asked subjects to solve tough visual recognition problems. They found the alpha entrainment helped them learn faster... Consumer grade EEG headbands could potentially be used to replicate this result... but someone should figure out whether this can be used for the sorts of things normal people want to learn."

Back to the technicalities of EEG. We start with non-invasive electrodes that are placed along the scalp. Placement diagrams are typically done using the international 10-20 system, where a measurement is taken across the top of the head from the nasion (point above the nose between the eyes) to the inion (the crest point of the back of the skull). It looks like this:



Each of the circles represents a potential electrode placement and has a letter to identify it by - for example, FP = pre-frontal; F = frontal; T = temporal; P = parietal; O = occipital; and A = the prominent bone usually found just behind the outer ear. These all match up to various parts of the brain that are responsible for sending different signals.

The signals from these electrodes typically go through electrical components known as op-amps to filter out potential interference from other factors, such as moving your head (this is why most EEG boards will also come with an accelerometer to cancel out said factor). Each electrode is considered to either feed into a positive or negative channel. (How do op-amps work? That's something I'm still trying to figure out, but the general idea is that it does two things in essence: takes the difference between an electrode signal and a baseline value, and then amplifies that value by a significant amount.)

After filter(s) are applied, the electrical signal, which is currently in analog form, needs to be converted to a digital signal. Most commercial EEG boards use some variant of the ADCs (analog-digital converter) that Texas Instruments manufacture; in our case, we're looking at the ADC1299, which has support for 8 channels.

It then goes through a microcontroller that transfers the data to a computer - through WiFi or direct transfer, or some variant of both. It's important to prevent interference from this as well, so having an external antenna or having the antenna be directly on the board is important. In our case, something like the ESP32S2MINI1U will suffice. Transferring the data makes use of a USB-to-UART converter.

And boom! You have an EEG board. (Easier said then done.) From there it's more software-based.