Low-cost brain-and-world-sensing eyeglass

Abstract—We propose an ultra-low-cost brain-sensing device based on infrared spectroscopy. The device is based on a simple ultra-low-cost transimpedance amplifier front-end and lock-in amplifier followed by a simple computational machine learning system that captures changes in blood oxygen levels in the brain and uses this information to infer a “dragging” (hypoxia), “rushing” (hyperoxia) or “flow” (in-between) state. The system uses a miniature camera to provide context-awareness and tags images with brain-state metadata to build a mental health database. It is our hope that context-aware brain sensing will produce positive mental health outcomes by helping us predict and warn of depression, stress, anxiety, panic attacks, etc., as well as create a visual annotated diary to help track down environmental causes of depression (e.g. “dragging”), stress, anxiety (e.g. “rushing”), etc.

Index Terms—Wearable computing, Wearables, BCI, brain-computer interfaces, sensing, metasensing, lock-in amplifier, fNIRS, infrared spectroscopy, Sensing, Mobile computing, Sousveillance.

Wearable sensing technologies can create new and extended human sensing capabilities which provide a Humanistic Intelligence (HI) feedback loop in which the human learns from the computer while the computer learns from the human. HI is also known as Human-in-the-loop AI, or “Wearable AI” [1].

We have built an ultra-low-cost eyeglass based HI device that senses the world around us together with the way in which our mind responds to that world. See Fig. 1.

lock in amplifier which is even more expensive, e.g. typically

Typically there’s a tough choice to be made between a software-based lock-in amplifier, which necessarily requires more expensive hardware analog to digital converters (e.g. need 24 bit or 32 bit analog to digital converter...) or hardware on the order of $10,000 (used PAR 124A for example) or $3000 (used SR510), and they are also bulky. See Fig. 2.

We use an off the shelf analog front end with a 19-bit ADC resolution for measurements pairing with commonly available LEDs and photodiodes to measure long and short paths of reflection.

We applied the Modified Beer-Lambert law [2] in real-time to compute estimated relative changes in oxygenated, de-oxygenated and total hemoglobin concentration change. Using adjustable DPF (differential path length factor) values we adjust the system on a person by person basis, as well as adapt over time using simple machine learning.

We have found success in overlaying the fNIRS estimated change values on top of an automatically captured image based on a relative change state index. When there is consistent change, the brain becomes more “activated” during the task and during excessive activation, “rushes” of blood flow to the particular region being measured can be detected. In our case the left and right temporal, inferior frontal gyrus junction, found on top of a pair of eyeglasses, is sensed. In general, low changes in oxygenated hemoglobin are associated with boredom [3], tiredness, and distraction, a state that we refer to as “dragging”. Mid-levels of oxygenation change are normal, which we refer to as “flow tempo”. High levels of oxygenated hemoglobin change indicate interest, excitement, arousal, stress, or simply intense physical activity, i.e. “rushing”. See Fig. 3. Note that “Rushes” can be good or bad (e.g. fun excitement or not-so-fun panic). The job of our machine learning is to use the video camera along with the brain data to tell the difference.

REFERENCES

