HI-Cam: Intelligent Biofeedback Signal Processing

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Abstract— **Humanistic Intelligence (HI) is defined by two embodying elements. (1) It is a signal processing framework in which the human and the computer use each other in a feedback loop. (2) The HI processing apparatus is inextricably intertwined with the natural capabilities of the human mind and body. The Humanistic Intelligent Camera, or HI-Cam, is a wearable personal imaging application of HI. It uses physiological signal processing such as Fast Fourier Transform (FFT) analysis on EEG signals to control various parameters of a personal cybernetics system. EyeTap [1] devices are particularly well suited to being controlled by brainwaves, because the parameters of the system are observable on the screen of the EyeTap viewfinder. This provided a direct means of physiological control over a video capture program, creating a camera system embodying humanistic intelliegence.**

I. Introduction

HUMANISTIC INTELLIGENCE (HI) is a signal processing framework in which the processing apparatus (such as a wearable computer) is inextricably intertwined with the natural capabilities of our human body and mind, working in parallel to integrate the user within a feedback loop of an intelligent control system. Research on the HI-Cam project focused on enabling the apparatus to learn what is visually important to the wearer and thereafter function as a fully automatic camera [2], taking pictures without the need for conscious thought or effort from the wearer.

The HI-Cam uses various forms of biofeedback to realize HI. These physiological indicators include electroencephalograms (EEG), electrocardiogram (EKG), respiration, skin conductance (SC), temperature(TEMP), and blood pressure (BP). Such biological signals processed by the HI-Cam can then be cross-referenced and conveniently displayed on the EyeTap viewfinder in a feedback loop. The use of EEG analysis, and a simple classifier enabled the device to control various parameters of a personal cybernetics system, such as increasing and decreasing the brightness of the video that was captured by a camera. The classifier was based on the motor related Mu desynchronization [3] of the signal obtained from one electrode that acquired the EEG signal. A practical application of HI-Cam is seen in Fig 1.

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Fig. 1. The wearable HI-Cam as worn by a participant while jogging. Biofeedback is through the viewfinder computer screen included in the EyeTap camera system of the sunglasses.

II. Apparattus

The HI-Cam apparatus consisted of the ProComp+ biofeedback device that was connected to the serial port connection of a wearable computer. The ProComp+ performed the acquisition of biological data from the participants, which was then fed into the wearable computer for processing and analysis. The ProComp+ biofeedback device, is essentially an Analog-to-Digital(A-D) converter that provided a digitized representation from the various physiological signals of the participants' body. There are eight channels on the ProComp+ device two for EEG, two for EKG, one for SC, one for BP, and one for respiration. Non-invasive cutaneous Ag/Ag-Cl electrodes connected the channels of the A-D converter to the participants, while a fiber optic cable allowed for transmission of data to the wearable computer.

III. Experiment

A. Data Collection and Display

Several participants who had at least a limited knowledge of the project took part in the experiment. One EEG electrode was sewn into a baseball cap which was isolated by a copper mesh. Recent studies have shown that in many instances a single electrode is sufficient for analyzing motor related mu desynchronization [4]. With the use of conductive paste, the electrode was applied to the vertex on the scalp. This location was chosen since the largest amplitude EEG activity can be picked up

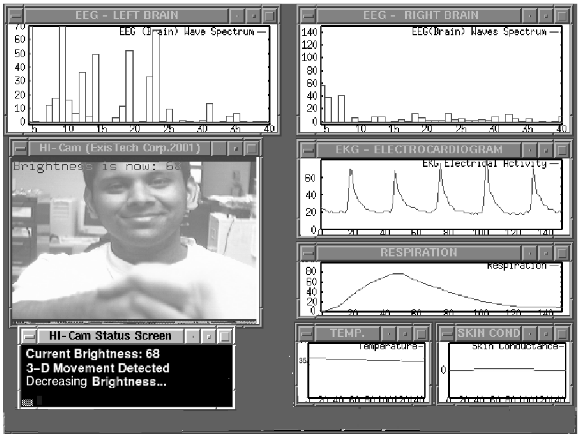

Fig. 2. The HI-Cam software runs in parallel with the body's physiology and provides visual feedback to the user through the EyeTap viewfinder as displayed in this screen grab.

at the vertex due to the sinus of cerebral spinal fluid (CSF) lying between the two hemispheres. EKG electrodes were connected to the mid-clavicular line in the 5th intercostal space of the participants, in close proximity to the heart.

The EEG data was collected at a sampling rate of 256 samples/sec through the EEG channel of the ProComp+. The right ear lobe was used as reference. Meanwhile, the EKG signal, respiration and temperature were also sampled at a frequency of 32 samples/sec and plotted in real-time to create a profile of the participants. The graphs of the temperature, EKG and respiration signals were continuously being updated and displayed on to the screen. The EEG data was being processed and an FFT power spectrum of the data was being displayed every 500 ms. The FFT power spectrum displayed a frequency range of 8-30 Hz. Using FFT analysis, a running average of the bandwidth power was updated and displayed on the screen every 500 ms.

B. Experimental Task

User control was realized by altering the average FFT coefficient power for the 8 - 30 Hz bandwidth making use of motor related mu desynchronization. This method allowed for 3 degrees of freedom in controlling the brightness of the screen.

The experiment consisted of a predefined task for the participants to increase the brightness of the captured video from an initial value of 0 % to 100 %, when the brightness had reached a 100% level he was notified by a beep. The participants then tried to bring down the brightness to 50% by opening their eyes, and consequently maintained that value for as long as possible.

IV. Data Processing

A. Frequency Selection and Classification

The 8-30 Hz bandwidth was chosen since these bands are known to be important for mu related desynchronization, or motor movement.

A simple classifier was used for this experiment. 1-second data segments with 500ms of overlap were analyzed using FFT. A signal $g(t)$ was analyzed by way of Fourier transform: $G(f) = FFT(g(t))$ Our classifier was based on the power given by $GG*/n^2$, where n is the number of data points in the signal. A discrete sum of the frequency powers between 8 and 30 Hz was obtained. This data was convolved and passed through a 3 tap rectangular filter. The data was updated and displayed every 500 ms.

B. Threshold selection and Artifact rejection

The thresholds for adjusting the brightness were selected by inspecting the displayed values for the average power during the training sessions while the participants performed three tasks. To ensure that the increase in the power of the frequency bands was not due to muscle artifact, an upper threshold was introduced beyond which the obtained power values were rejected. Thus the brightness was changed according to the particular region the power was found to be in.

V. Discussion

The HI-Cam apparatus, which is portable and simple in nature, proved to be a reliable means of utilizing the natural capabilities of the human body and mind to interact with the physical world. The real-time physiological signals processing with the help of biofeedback strategy, proved capable of extracting and classifying patterns, which could be interpreted by the computer to control screen brightness.

An application of HI-Cam could include monitoring the user's physiological state so that warning signs of personal danger could be detected. The HI-Cam would also be excellent for wearable computing systems with head mounted displays, where the user's current physiological and mental state could control the nature of the display. HI-Cam is already able to distinguish when a user is drowsy, concentrating, or at rest. For example, HI-Cam could be used to assist narcoleptic patients drive safely. Unlike clumsy eyetracking devices, the HI-Cam is unobstructive and comfortable. HI-Cam also provides a more accurate description of the user's state, since it provides direct measurements from the user's brain, rather than making inferences based on eye movements. Thus, the non-invasive, wearable, and convenient characteristics of HI-Cam makes it practical for it to act as a natural extension of the human body and mind.