Measuring Biological Signals:
Concepts and Practice

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Abstract
Participants will learn the conceptual and practical considerations for measuring biological signals to create dynamic new forms of self awareness, personal expression and interpersonal communication. Using a provided breadboard and off-the-shelf electronics (no soldering required), participants will construct simple circuits and learn the basic concepts required to measure (1) galvanic skin response (GSR), (2) heart rate (EKG), and (3) brain activity (EEG) for implementation in wearable devices, art, industrial applications, and more.

Keywords
biofeedback, wearables, wearable computing, emotion, galvanic skin response, GSR, heart, heart beat, heart rate, EKG, ECG, brain, EEG, biological signals, self-awareness, expression, communication

ACM Classification Keywords
J.3 LIFE AND MEDICAL SCIENCES – Health
J.3 LIFE AND MEDICAL SCIENCES – Medical information systems
J.4 SOCIAL AND BEHAVIORAL SCIENCES - Psychology
J.4 SOCIAL AND BEHAVIORAL SCIENCES – Sociology
J.5 ARTS AND HUMANITIES – Arts, fine and performing
J.7 COMPUTERS IN OTHER SYSTEMS – Consumer

products
J.7 COMPUTERS IN OTHER SYSTEMS - Military

Introduction

Interpersonal communication has historically been limited by the ways in which our bodies can sense the world. Beneath the skin, however, our bodies generate dynamic electrical and chemical signals that carry information about our senses, thoughts, emotions and responses to the world. Modern embedded and off-the-shelf technologies make it readily possible to measure biological signals and use these signals to create new forms of expression and communication. Participants in the studio will learn how to make simple circuits from off-the-shelf components that detect biological signals. These will include circuits that (1) Measure and display the galvanic skin response (GSR, a common component of lie detector tests) revealing heightened emotional responses. (2) Measure heart rate (EKG) easily and cheaply using off-the-shelf exercise equipment. (3) Detect and analyze brain activity (EEG) using a microcontroller that is pre-programmed to perform a Fourier analysis to separate different types of brain activity for display on RGB LEDs.

Examples of these circuits embedded into clothing (as seen in Figure 1 and at http://www.produceconsumerobot.com/vitalthreads/) will be worn throughout the studio and Truth Wristband Kits (http://www.produceconsumerobot.com/truth/) will be available for eager studio participants to purchase and assemble. The concepts underlying these measurements as well as the pitfalls of using these and other approaches to measuring biological signals will be discussed. The philosophical considerations of acquiring and networking biological signals will be also discussed.

figure 1. Clothing with embedded circuitry to measure and display biological signals of the wearer. The Truth Wristband displays the wearer's emotional responses by measuring the galvanic skin response. The Heart-felt Shirt flashes with the wearer's heart beat. The Thinking Cap displays changes in neuronal synchrony on 6 modular RGB arrays.

Studio Proposal

After introductions, the studio will begin with a discussion (20-30 minutes) of (1) different biological signals and what information they can offer (2) philosophical considerations discussing possibilities and potential problems of a future with widespread monitoring of biological signals.

The remaining studio time will be divided up to cover each of the 3 circuits. For each circuit, we will discuss in greater detail the concepts and practical considerations followed by a period for participants to put together their circuits, evaluate their circuits on test equipment and their own biological signals, and explore how biological signals change within group dynamics.

The studio will conclude with a slot of time allotted for participants to reflect on how the things they have learned could be worked into their own projects and society at large.

No knowledge of biology, mathematics, or microcontrollers will be assumed. Some basic level of comfort implementing circuits on a breadboard is optimal, but all are welcome. Anyone who has experience programming PIC microcontrollers is welcome to bring their own computer/programmer to test different parameters.

Studio Topics to be covered

Participants will learn how to construct circuits using simple, off-the-shelf electronic components to measure biological signals. Three circuits will be constructed on provided electronic breadboards (no soldering required).

1) Measuring the Galvanic Skin Response (GSR)
Using an op amp, some resistors and capacitors, a pre-programmed microcontroller and an LED, participants with create a circuit to detect peaks in skin conductance accompanying emotional arousal.

2) Measuring Heart Rate (EKG)
Participants will learn how to setup and use an off-the-shelf chip (Polar RMCM01) for measuring heart beat information sent from various Polar heart straps and transmitters.

3) Detection and Analysis of Brain Activity (EEG)
The brain uses rhythmic oscillations at different frequencies to synchronize neuronal activity in different brain regions. Built in FFT functions of modern microcontrollers make it possible to create embedded circuitry that can do basic analysis of brain activity. The studio will cover the essentials of implementing FFT in a PIC microcontroller and participants will wire up a preprogrammed PIC that reads in brain activity, performs an FFT to separate the different frequency bands and displays changes in Alpha (~10Hz), Beta (~20Hz), and Gamma (~40Hz) oscillations on 3 RGB LEDs.

Studio Learning Goals

1) Learn how to make circuits that:
   a) measure the galvanic skin response
   b) measure heart rate
   c) separate different brain oscillations for display on RGB LEDs.
2) Learn the basic concepts and pitfalls of measuring biological signals using different approaches.
3) Think about the future possibilities and problems in a world where monitoring of biological signals is likely to become more ubiquitous.

Studio Supporting Web Documents

http://www.ProduceConsumeRobot.com/TEI2010/