

## THE "CONDUCTOR'S JACKET": A DEVICE FOR RECORDING EXPRESSIVE MUSICAL GESTURES

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### Abstract

We present the design and architecture for a device called the "Conductor's Jacket," which we built to collect and analyze data from conductors. This device is built into normal clothing and designed in such a way as to allow for normal activity and not encumber the movements of the wearer. The jacket records physiological and motion information from musicians in order to better understand how they express affective and interpretive information while performing. We present our design considerations and some preliminary results from data collection trials that we conducted on a range of professional and student conductors in 'real-world' situations.

### 1 Introduction

A common issue encountered in the development of new instruments is the question of how to map the input control stream (often in the form of transduced gestures) to the output audio stream. That is, how to generate complex musical responses that coherently reflect the intentional information contained in gestural inputs. Often, designers of interactive performance systems choose mappings that apply one continuous axis of the input control stream to a single continuous parameter at the output stream. This method often yields a clear and useful result, but has limitations. For example, if there are characteristics or patterns in the performance of the gesture that require interpretation, then more complex methods are required.

We are interested in building a system that recognizes and responds appropriately to expressive features in musical gestures. The first phase of this project involves designing and building a reliable system to collect data from musicians in real performance situations. The second phase involves analyzing the data to learn features that are natural indicators of musical expression. Both of these phases are aimed at learning more about how musicians naturally modulate their gestures and physiology when they perform music, so that better mappings can be developed between the input gestures and the output audio stream. The final phase of this project will involve constructing such mappings for the system described below.

We chose to focus on conductors because they use a highly specific code of gestures in order to indicate the expressive and interpretive elements in the musical structure. Additionally, conducting gestures often indicate more global phenomena than the individual note events and are not constrained by the requirements of performing on a mechanical instrument.

The data-acquisition system described in this paper, which we call the "Conductor's Jacket", is a wearable array of sensors, communications, and computation, which detects and records physiological changes and physical motion without interfering with the way that the gesture is naturally performed. This approach builds upon experimental and analytical techniques developed for situations involving human affective communication [Healey and Picard 1997, Picard 1997]. We present the system architecture and design considerations below, along with preliminary results from use of this system by three professional conductors and four conducting students.

### 2 The "Conductor's Jacket" System

The most important human factor in the design of our system was the need to provide a device that would not constrain, encumber, or cause discomfort to a conductor during standard rehearsals and performances. We felt strongly that we should gather data in a professional context, as opposed to a laboratory simulation, in order to generate useful and significant results. Because of this choice, we had to conform to the demands of a rehearsal situation and be sensitive to the conductor's agenda. The outfit would have to be easy to put on and take off, simple to plug in, allow for free movement of the upper body, and be robust enough to withstand the lively, energetic movements of an animated subject.

Given these constraints, we decided to focus on signals that could be detected at the surface of the skin in a relatively simple way. Drawing upon previous work from the M.I.T. Media Lab's Affective Computing Research Group, we chose to focus on physiological sensors that give clues to the wearer's emotional state and that provide information about the projected gestures of the conductor. The final system contains one electromyography (EMG) sensor on each bicep and forearm extensor, together with sensors for respiration, temperature, skin conductance, and heart rate. In addition, we used sensors that measure 3D position and orientation on each wrist, elbow, shoulder, nape of the neck, and small of the back.

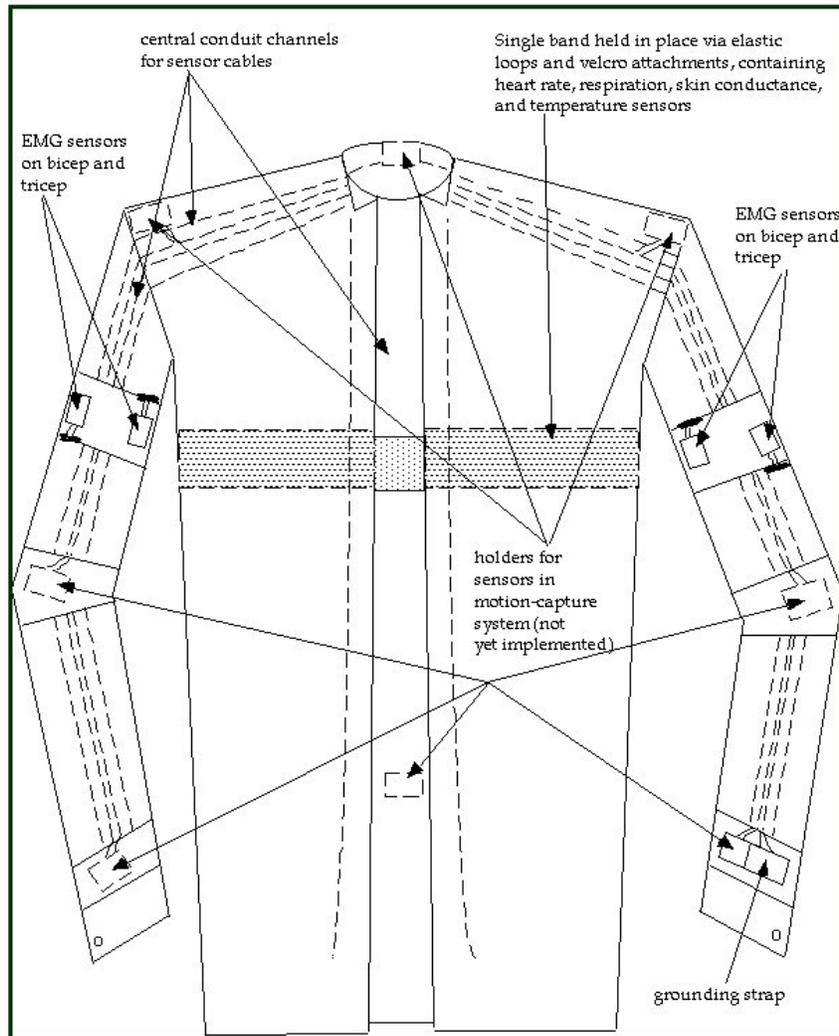


Figure 1. Placement and integration of sensors into the jacket.

The 'jacket' is a specially adapted shirt designed to accommodate and hold the different sensors in place. The design shown here was originally intended to be unobtrusively placed under normal clothing, although an alternate version was also made. The alternate version was functionally equivalent to the original, but deliberately designed to "show all the wires." Hence, the appearance of the system (such as a traditional tux with no wires showing, or a "wired look") is up to the wearer, and the style of the clothing is functionally irrelevant. Elastic armbands hold the EMG sensors against the skin, with strain-relief sewn into the cloth. Special channels sewn onto the outside of the arms, shoulders and back of the outfit act as conduits for the cables, which join together and lead to a small plug that is in turn cabled to a nearby computer. All wires and cables are looped to minimize stress on the connectors as well as on the wearer.

The EMG sensors provide a differential, 1000x amplified measurement and are made by Delsys Inc., a company that specializes in electromyography. The heart rate sensor is a Polar Heart Monitor, available in stores that sell athletic training equipment. The other physiology sensors are manufactured by Thought Technology Inc., which develops portable systems



for medical monitoring. The motion sensors were part of an “UltraTrak” motion capture system, which was loaned to us by the Polhemus Corporation. All the sensors are noninvasive and are held in place by means of elastics and straps; no messy gels or adhesives are used. When worn and plugged in, the current version of the Conductor's Jacket provides approximately twenty feet of maneuvering space around the computer. While a fully wireless system remains in the future, the twenty-foot radius was sufficient for both orchestral rehearsals and a live professional performance. This distance also ensures that the limited mouse-clicking and typing required for running the data acquisition utilities are far enough away from the conductor so as not to be disturbing.

In addition to the wearable sensor web, the Conductor's Jacket consists of a data acquisition system running on a PC. For this we chose to use an open architecture, so as to be able to integrate and swap between numerous sensors from different manufacturers. In the current version, the raw voltage outputs from the eight physiological signals are routed through an external terminal box. The signals are then sent to a board inside a PC where they are sampled at 1 kHz with a 16-bit A/D converter.

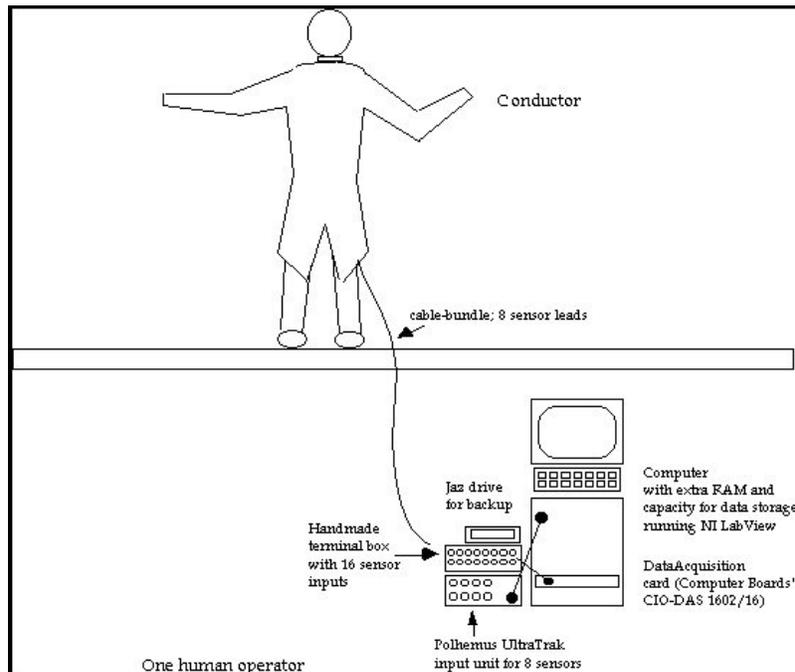


Figure 2. Hardware Architecture for the Conductor's Jacket.

Utilities were written in National Instruments' Labview software package to process, filter, graph, index, and write the data to files. These allow the computer operator to quickly manipulate the graphical output of the data for debugging purposes, as well as to trigger the A/D converter and naming and writing to files in various locations. A digital video camera was used at every data collection session in order to capture a high-resolution, time-indexed record of the events in the rehearsal. The video is useful in gathering accurate annotations, for example, to confirm that a particular conducting gesture was indeed 'cueing the winds' versus 'waving to an observer.' The video is not part of the wearable conducting system, although there exist wearable video systems which record their wearer's gestures through a camera [Starner, Weaver, and Pentland, 1997]. We chose to keep the equipment worn by the conductor as natural in appearance as possible; consequently, we chose a freestanding camera that was only used by us for labeling data.

### 3 Conclusions and Future Work

The "Conductor's Jacket" is an ongoing project, the first phase of which has been completed: the design of an accurate, robust, comfortable, and unobtrusive wearable sensing system, capable of recording not only gestural motion information, but also expressive aspects of musical gesture. The system has been successfully used in data collection events during classes, rehearsals, and live concert-hall performances of seven conductor subjects over a four-month period. These subjects spanned a range of abilities, from conservatory students to prominent professionals. On average, it took six minutes to 'suit up' each conductor, which comfortably met the requirements of even busy performers' schedules. Difficulties were occasionally

encountered in adjusting the sensor placement on different individuals (resulting in certain sensors losing contact or recording motion artifacts and noise), but the design, if properly positioned initially, was able to gather good data over lengthy rehearsal and performance sessions (up to three hours) without encumbering the wearer.

The large data sets from these events are being analyzed and will be applied to build user-dependent models for real-time recognition of expressive gestures. Features of the data that have been identified so far include significant variations between the physiological signatures of different individuals, as well as the expressive prominence of bicep EMG and respiration signals. These results will be reported in a forthcoming publication.

Work is underway to make future versions of the "Conductor's Jacket" entirely wireless, either by means of wired sensors connecting to a wearable computer, or via wireless transmission at each sensor itself. We are also exploring other applications of this interface in the areas of affect recognition and stress evaluation. It should be noted that while the "Conductor's Jacket" is designed only to sense the motions of the torso and arms, it might be combined with another hand-held interface, to augment the amount of input control. Also, while this project does not sense the articulations of the face or hands, there could be great value in adding features for detecting such gestures.

The "Conductor's Jacket" is an ongoing project, involving not only the design of a physical system, but also the learning of natural, intuitive, and expressive mappings for musical gestures. The development of the system described here has enabled accurate collection of musical gesture information from professional conductors in real performance situations. It is our hope that this system will not only provide a rich source of information on the physiology and mechanics of conducting, but also will be of creative use in expanding the potential of new expressive performance systems.

#### **4 Acknowledgments**

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