

# DESIGNING AN INTEGRAL MUSIC CONTROLLER

*INTRODUCING BIOSENSING AND EMOTIONAL  
STATE ESTIMATION TO GESTURAL CONTROL OF  
SOUND SYNTHESIS*

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A Presentation for HUMAINE Summer School 2006

# Overview

1. Review of Physiological Signals Used in “BioControllers”
2. The Physiological Interface Problem and Possible Solutions
3. The Signal Processing Problem and Possible Solutions
4. HCI Scenarios for “Biocontrollers”
5. An Interaction Model of Musical Expression
6. The Integral Music Controller (IMC)
7. An Example: VAChorale

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# Review of Physiological Signals Used in “Biocontrollers”

	<b>Broad Definition</b>	<b>Possible Uses in Bio</b>	<b>Where Can It Be Measured</b>
<b>Galvanic Skin Response (GSR)</b>	Refers to the change in skin conductance caused by changes in stress and/or other emotional states. It is different than other bioelectric phenomena because it is measured by applying a signal and measuring the response	Used to aid in the assessment of emotional state. Most used of the original polygraph signals for measuring stress (e.g. Nasoz et.al., 2004)	Typically measured on the finger tips, palms, or bottom of feet.
<b>Electrocardiogram (EKG)</b>	Created by the electric Impulses of the heart as it progresses through the stages of contraction. The EKG is one of the largest bioelectric signals.	Used to aid in understanding of activity and emotional state	Needs sensors on either side of heart. Thus, chest strap, watches that require the opposite arm to touch a button, or two armbands are necessary. If only heart rate is desired, alternative methods such as pulse oxymetry can be used.

# Review of Physiological Signals Used in “Biocontrollers”

<p><b>Electrooculogram (EOG)</b></p>	<p>Caused by corneal-retinal potential. The signal varies nearly linearly within 30 degrees of center.</p>	<p>Used to measure eye motion for gaze tracking, emotional state and attention assessment (e.g. Knapp et. al., 1995)</p>	<p>Horizontal motion is measured on forehead using headband, vertical motion needs sensors below the eyes which require a glasses style interface</p>
<p><b>Electromyogram (EMG)</b></p>	<p>Measures underlying muscle activity generated by the firing of motor neurons</p>	<p>Used to measure arm and facial gestures (continuous control and state recognition), as well as a component of emotional state assessment (e.g. Englehart et. al., 2001)</p>	<p>Can be measured above any muscle including arm (using armband) and face (using headband or glasses)</p>
<p><b>Electroencephalogram (EEG)</b></p>	<p>Created by the cognitive and autonomic activity of the brain.</p>	<p>Used for emotional state assessment and “cognitive gestures” (i.e., using particular thoughts to elicit particular actions) (e.g. Wolpaw et. al., 1998)</p>	<p>Typically measured using massive arrays placed on head using baseball cap. For true commercial applications, must be measured using the forehead and mastoid</p>

# Paths to the Underlying Physiology



fMRI



EEG Array



Biocontroller

Increasing Mobility / Decreasing Cognitive Information

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# The Interface Problem:



- Electrode Placement
- Wearability



# The Interface Solution



## Electrode Placement:

- Must be able to be worn as part of normal technology-based clothing:

Embedded in fabric, watch or other armband, headphones, glasses, or other headband, or in the grip of a steering wheel or game controller

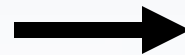
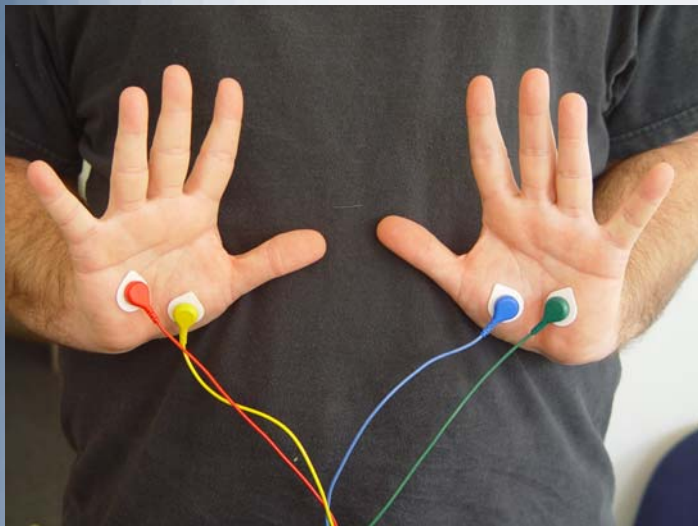
- The only acceptable locations for sensors not embedded in clothing are on the arms, hands, forehead, and mastoid.

## Wearability:

- Must use dry electrode with little to no preparation



# GSR / EKG



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The Integral Music Controller  
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# EEG / EOG / Facial EMG



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# EMG Measurement



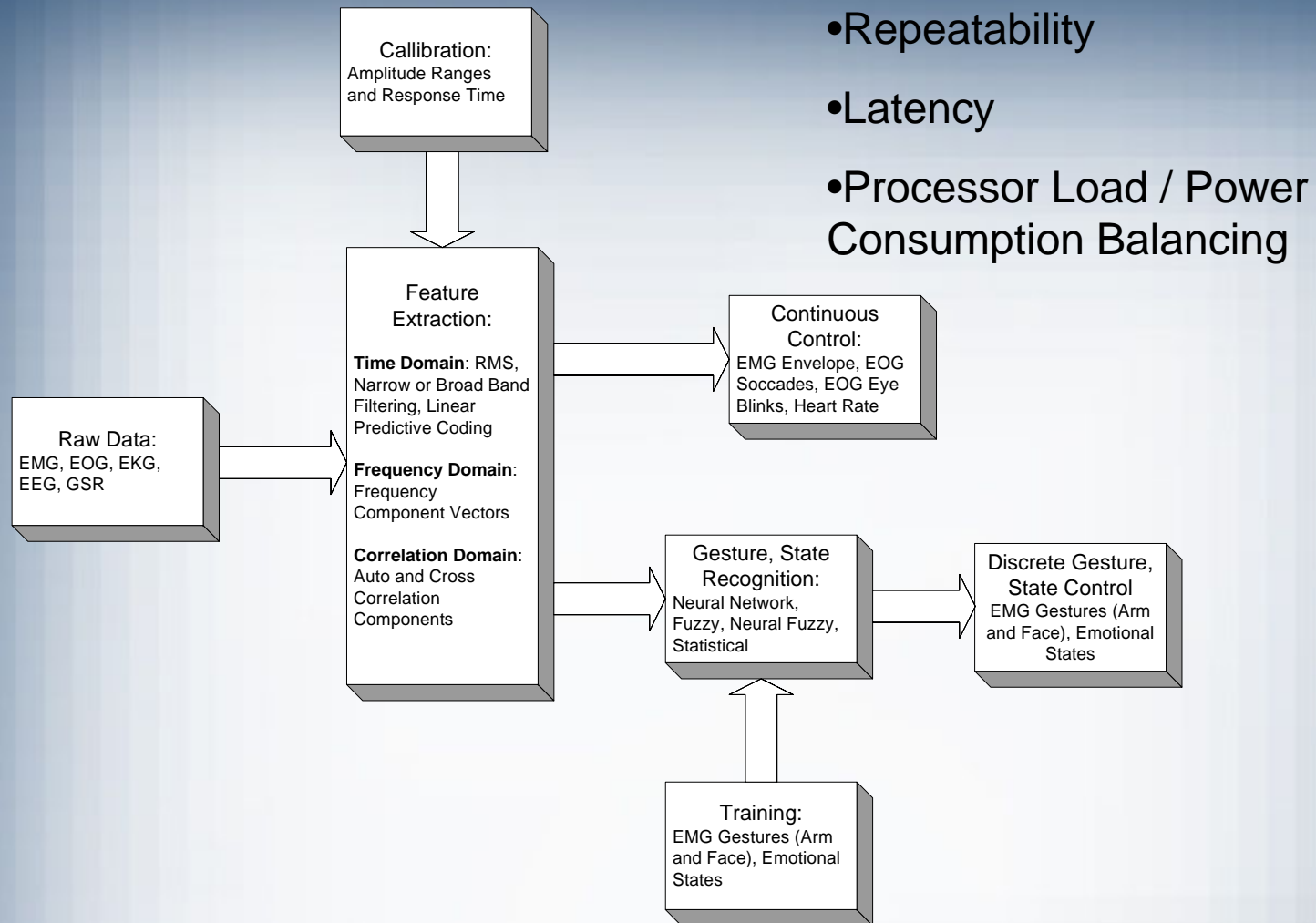
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# The Signal Processing Problem



- Repeatability
- Latency
- Processor Load / Power Consumption Balancing

# The Signal Processing Solution



## Repeatability:

- Must be capable of initial and ongoing calibration

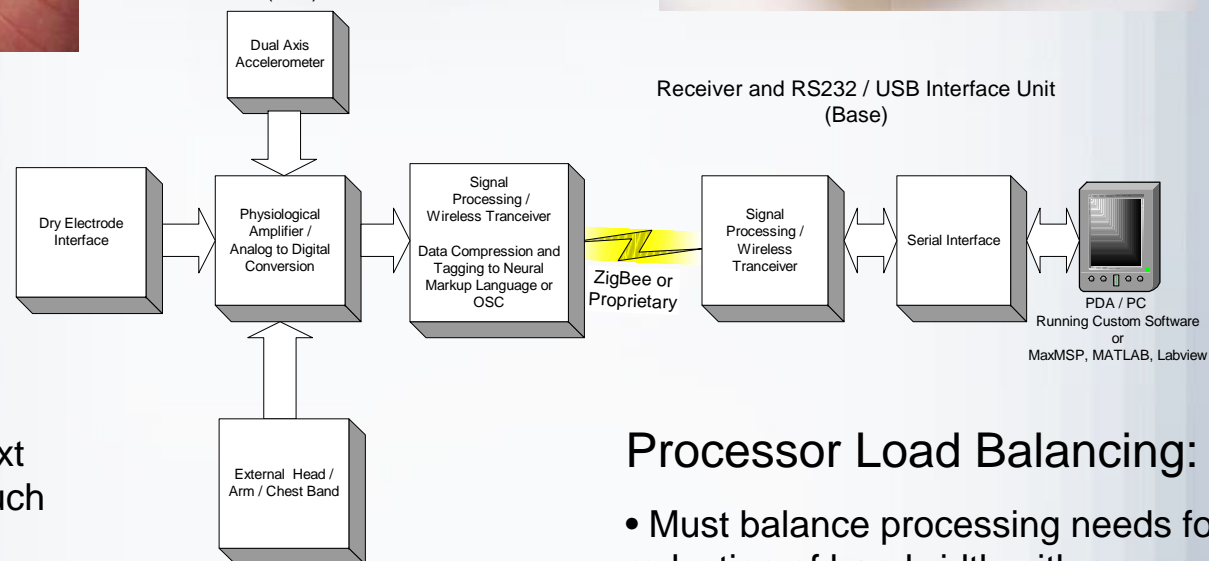


Data Acquisition and Transmitter Unit (Pod)

Receiver and RS232 / USB Interface Unit (Base)

## Low Latency:

- RF Protocol must be high speed with low overhead
- Pre-processing must compress using context based compression such as the Neural Markup Language



## Processor Load Balancing:

- Must balance processing needs for reduction of bandwidth with power consumption (MSP430)

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# HCI Scenarios with Associated Biocontroller Constraints

	<b>Signals / Application</b>	<b>Sensor Placement</b>	<b>Wearability</b>	<b>Processor Requirements</b>	<b>Communications</b>
<b>Operator Monitoring</b>	<i>GSR, EKG, EOG</i>  Emotion (Stress), Fatigue, Eye movement	Steering wheel, gloves, watch	Only dry electrodes	Low latency	Wired into the vehicle or wireless communication to vehicle
<b>Video Game Control</b>	<i>GSR, EKG, EMG, EOG, EEG</i>  Emotion (all achievable states)  Arm and facial gesture (continuous control and state recognition),	Game Controller handset, glasses, watch	Only dry electrodes	Low latency  High resolution	For safety, direct connection usually desired

# HCI Scenarios with Associated Biocontroller Constraints

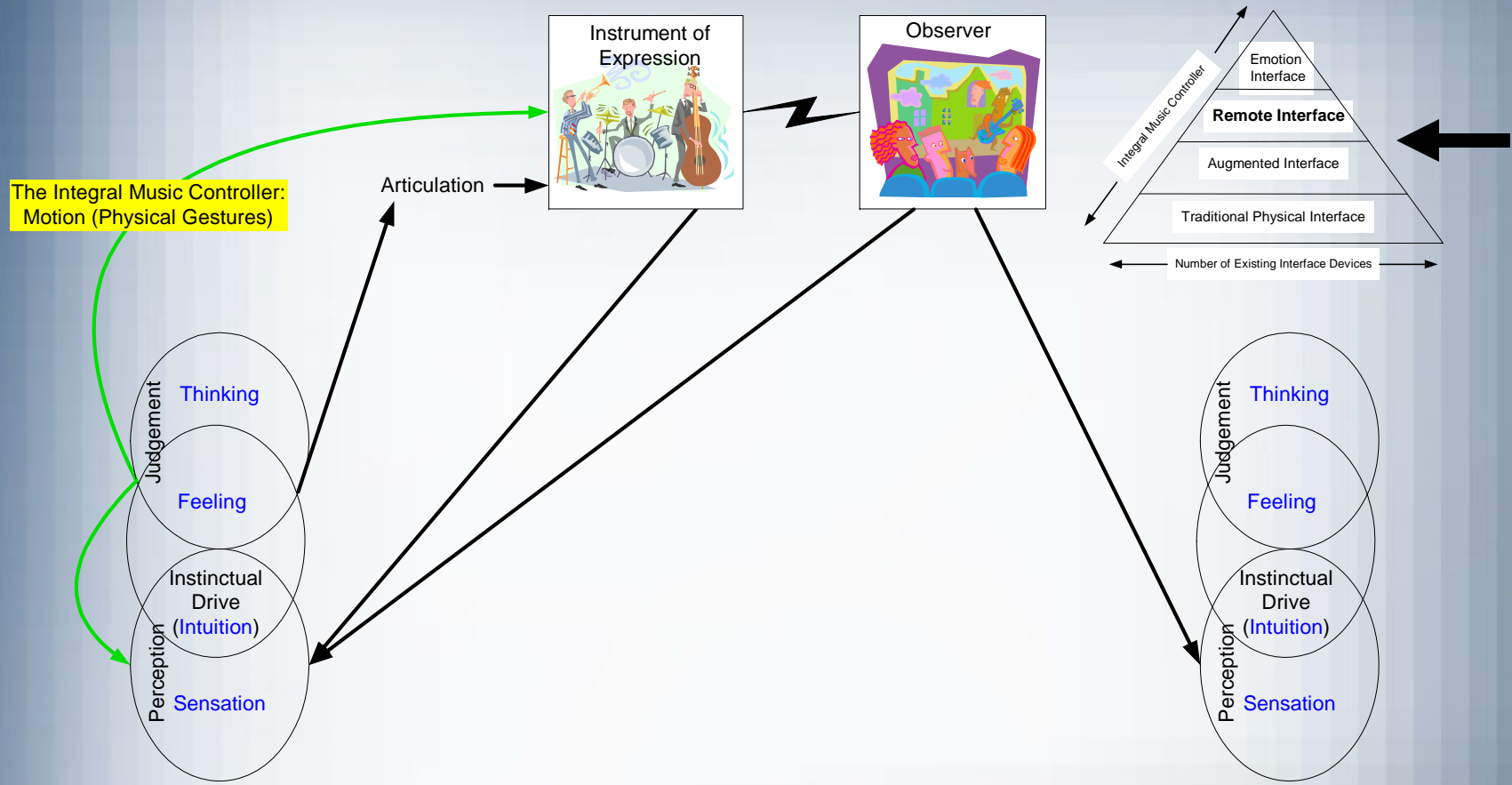
<b>Artistic Performance</b>	<i>GSR, EKG, EMG, EOG, EEG</i>  Emotion (all achievable states)  Arm and facial gesture (continuous control and state recognition),	Arm bands, Headbands watch, gloves	Only dry electrodes	Low latency  High resolution  Low power	Wireless system required – noisy 2.4 GHz environment might require custom RF approach
<b>Interfaces for Disabilities</b>	<i>GSR, EKG, EMG, EOG, EEG</i>  Arm and facial gesture (continuous control and state recognition)  Brain computer interface (BCI)	Arm bands, Headbands glasses, watch	Possible use of Hydrogel electrodes for EEG and EOG	Low latency  High resolution  Low power for wireless scenarios	Wired for computer use; wireless for mobile control of devices such as wheel chairs

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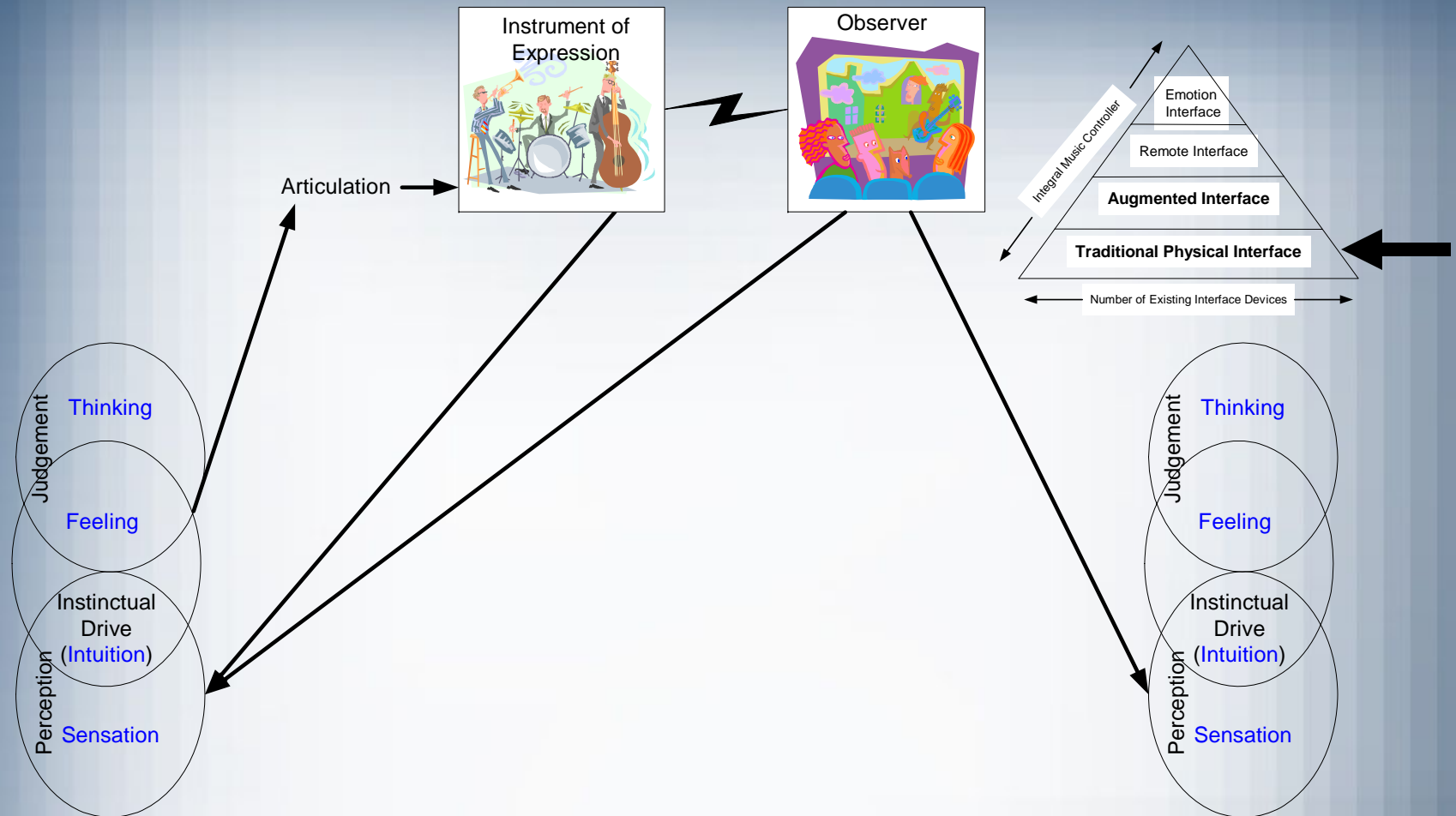
# An Interaction Model of Expression – Emotion is expressed through movement and intention

Interaction is created through direct measurement of motion and measurement of physiological signals (EMG) that represent motion and intent



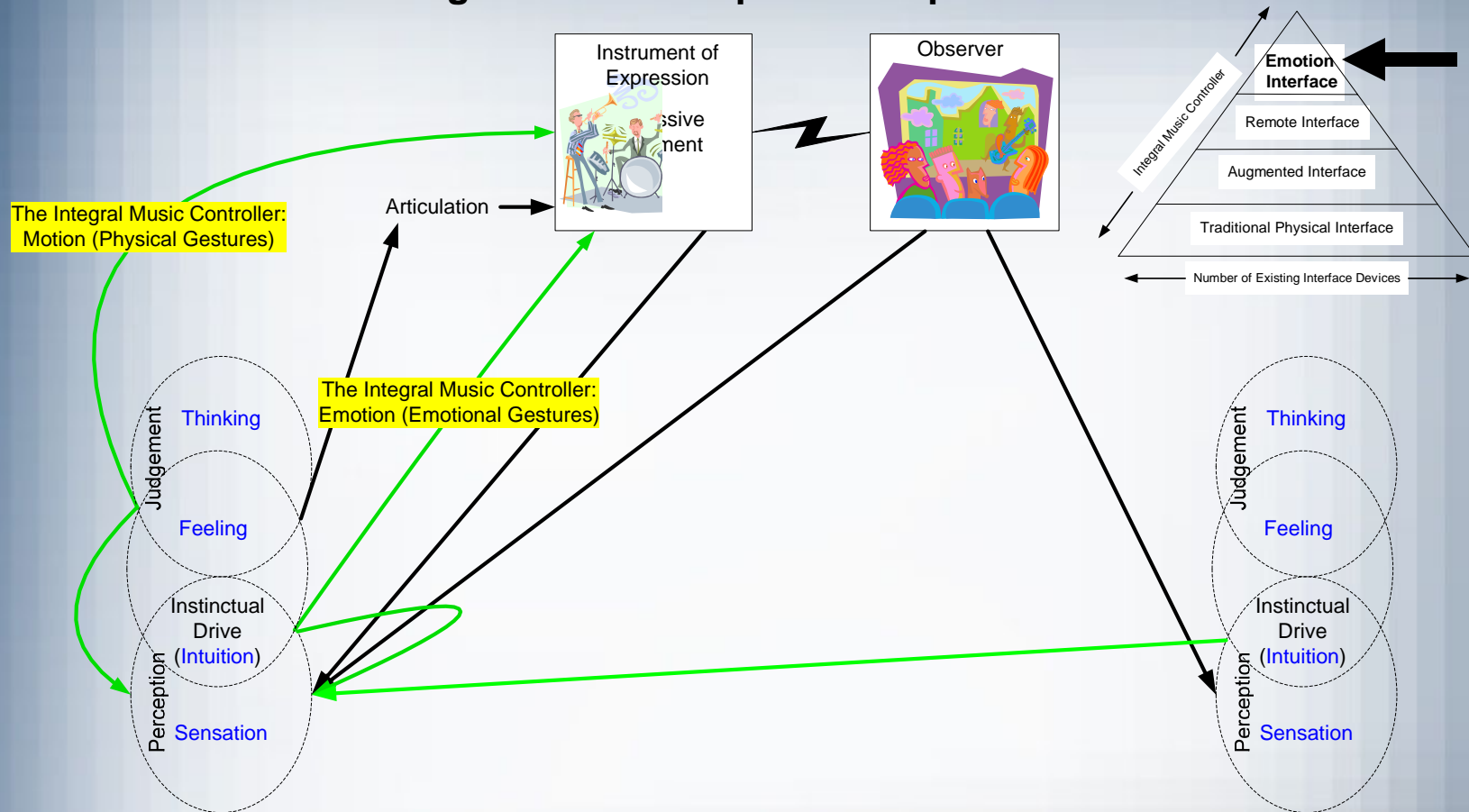
# An Interaction Model of Expression – Emotion is expressed through movement

Interaction is created through physical articulation



# An Interaction Model of Expression – Emotion is expressed directly

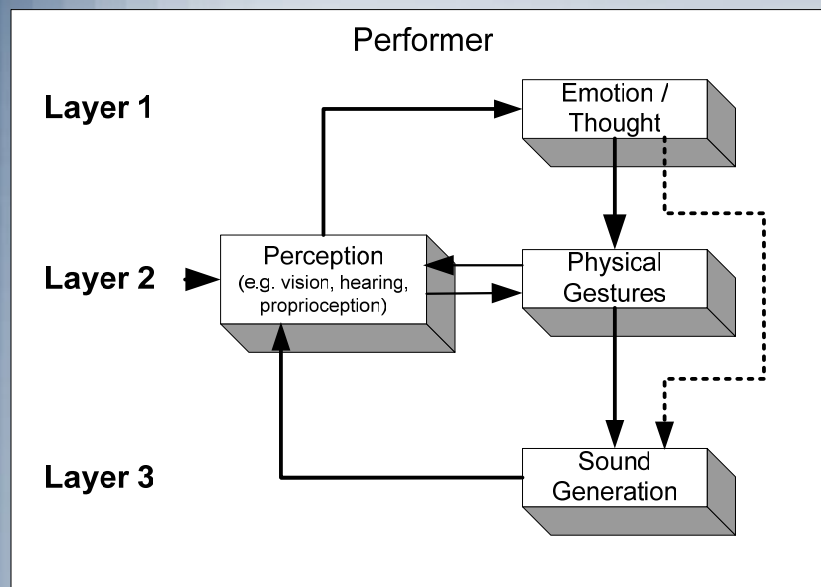
Interaction is created solely through measurement of physiological signals (EMG, EEG, GSR, EKG,...), vocal characteristics, and facial gestures that represent aspects of emotion



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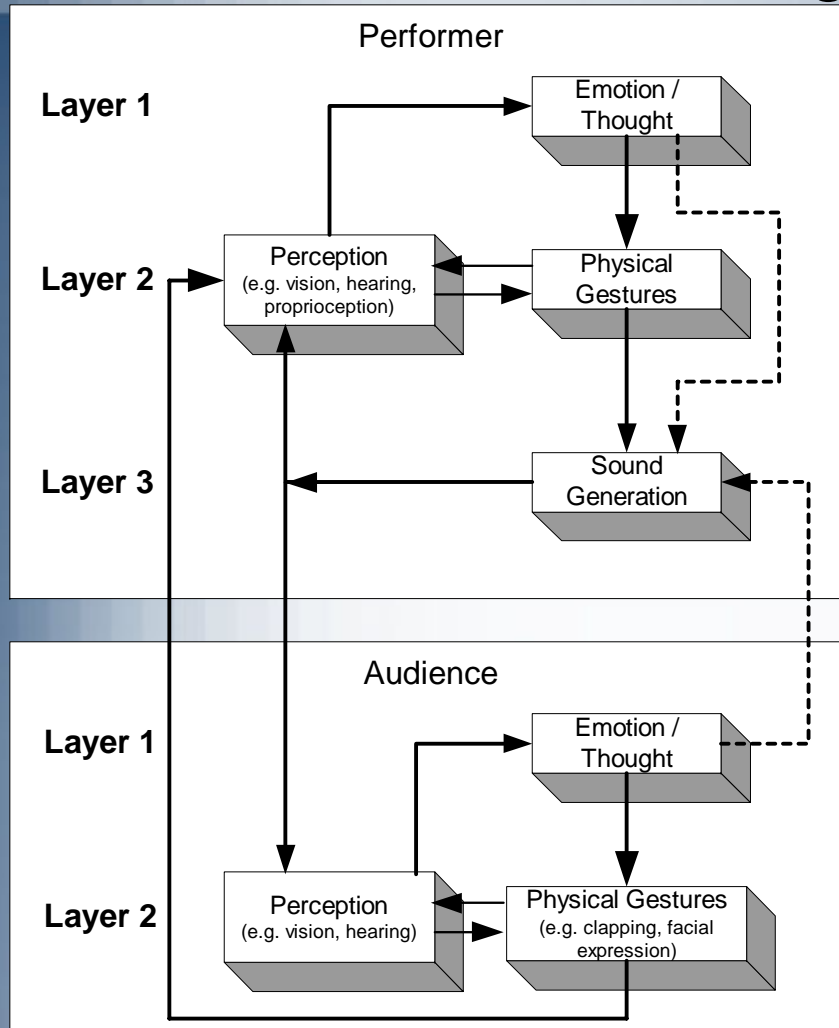
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# The Integral Music Controller



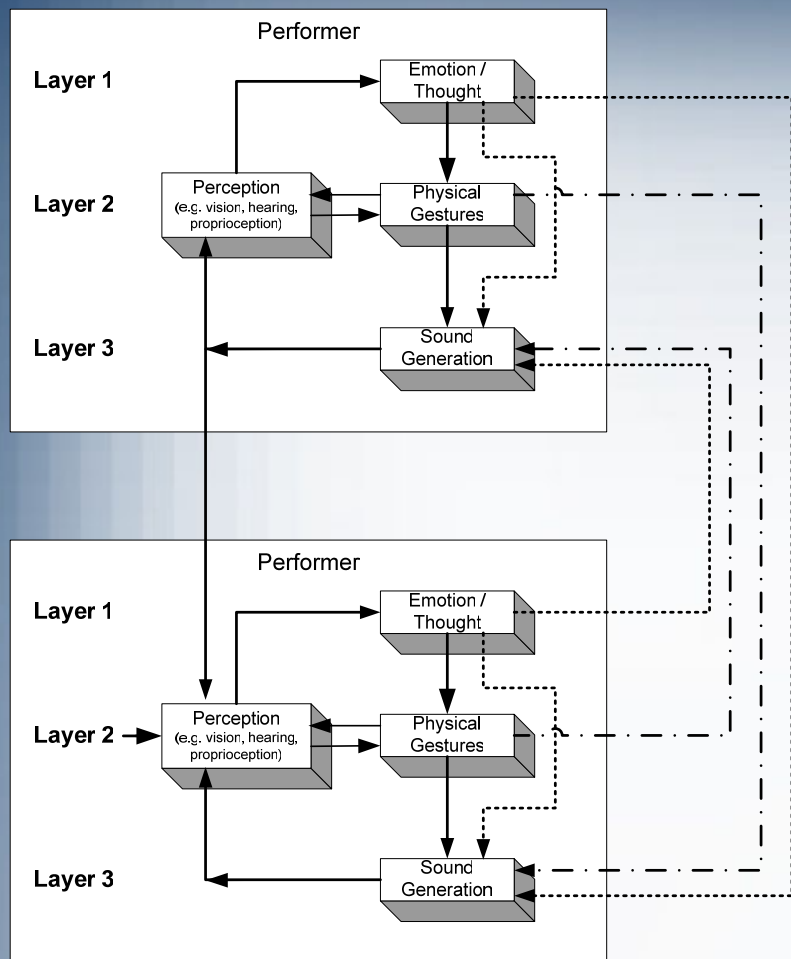
- Introduces Direct Path of Emotional Interaction: Direct expression of emotion into composition and performance
- Incorporates all levels of control from augmented through pure emotion
- Emotion Control bypasses/augments physical gesture
- Feedback of knowledge of performer's own emotional state into performance

# The Integral Music Controller: The Audience is Listening



- Direct feedback from audience is also possible
  - Assessment of audience reaction
  - Real-time interaction

# Networking The Integral Music Controller



- IMC interaction at the controller level
- Group improvisation augmented by group emotional state

# Possible Musical Control Paradigms – What Real Use is an Integral Music Controller?

## Performer / Composer

- Direct expression of emotion into composition and performance
- Feedback of knowledge of performer's own emotional state into performance
- Group improvisation augmented by group emotional state

## Audience

- Assessment of audience reaction
- Real-time interaction

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# The Virtual/Augmented Chorale Project

*(with Perry Cook – Princeton)*

## Traditional Performance

- Choir singing early music

## Integral Control

- Physical gestures including arm (EMG and accelerometers), face (facial tracking), and vocal characteristics as well as physiological parameters such as facial EMG, blink rate, GSR, and EKG.

## Augmented Performance

- Vocal characteristics, e.g. room acoustics, harmonizing, etc., modified based on IMC

## Remote/Emotional Performance

- Pre-recorded Voice(s) from speaker below each singer controlled by IMC – physiological, facial, and voice parameters to assess physical and emotional state.
- Vocal Model (Sheila) also controlled by IMC

# The Virtual/Augmented Chorale Project

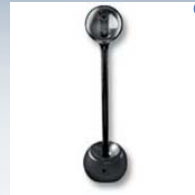
## The Choir

PLOrk



VACHorale

## Network of Integral Music Controllers



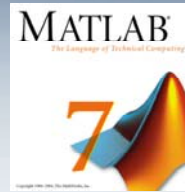
Audio / Visual



Physiological / Motion

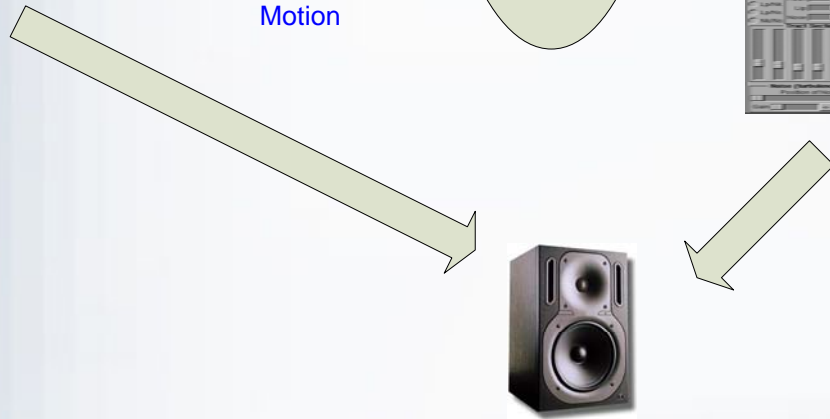
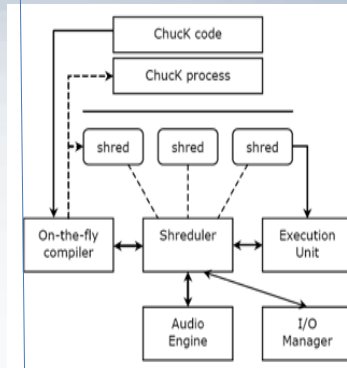
### Integral Parameters

- Facial Gesture
- Vocal Properties
- Physiological Parameters:  
EMG, GSR, EKG, EEG



## Network Fusion

Chuck



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