Kinesonic Approaches to Mapping Movement and Music with the Remote electroAcoustic Kinesthetic Sensing (RAKS) System

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ABSTRACT
Sensor technologies allow for a direct link between a dancer's kinetic and kinesthetic experience and musical expression. The Remote electroAcoustic Kinesthetic Sensing (RAKS) system, a wearable wireless sensor interface designed specifically for belly dance, enables such a link. *Teka Mori* (2013) for belly dancer, RAKS system, and computer-generated sound, explores a kinesonic approach to mapping belly dance movement to timbral control in electronic music.

Author Keywords
Interactive music; dance; sensors; synthesis; mapping.

ACM Classification Keywords
H.5.5. Information interfaces and presentation (e.g., HCI): Sound and Music Computing—Systems. J.5. Arts and Humanities: Performing arts (e.g. dance, music).

INTRODUCTION
For a dancer, movement produces interoceptive (inwardly directed) kinetic and kinesthetic experience. Sensor technologies enable the translation of internal experience to an external (exteroceptive) medium [13]. In electronic music, the generation, output, and mapping of movement data to musical parameters enable a direct link between movement and musical expression. A *kinesonic* approach foregrounds embodied activity by integrating movement, kinetic and kinesthetic experience, and sonic elements [9]. Through this lens, we discuss the Remote electroAcoustic Kinesthetic Sensing (RAKS) system, a wearable wireless sensor interface designed specifically for belly dance movement. We focus on how gesture attributes of belly dance movement vocabulary influence the interface design and mapping strategies in *Teka Mori* (2013) for belly dancer, RAKS system, and computer-generated sound.

Integrating movement, kinesthetic response, and sonic elements, the RAKS system enables a kinesonic approach to mapping movement and music. Designed to capture torso and hip motion, important movements in belly dance, the RAKS connects choreographic and musical gesture through strategic mapping in the software. We employ standard mapping relationships (one-to-one, one-to-many, many-to-one) as well as more complex temporal mappings [5] that integrate rates of change in the movement and sonic elements. These mappings correlate movement and music, articulating the bi-directional nature of this relationship.

BACKGROUND
The development of a kinesonic approach to interactive music for dance is rooted in studies of musical gesture [3, 6, 7], typologies of musical gesture in Human-Computer Interaction (HCI) [1, 14], and methods of gesture-to-sound mapping [2, 5]. Additionally, dance scholarship outlining frameworks for describing movement quality [10] and correlating movement and music [4, 8] informs this approach. A kinesonic approach synthesizes these theoretical and interpretive frameworks and employs an embodied perspective that guides the process of mapping movement and sound. The RAKS system developed from the authors' interest in combining belly dance and live electronic music performance.

REMOTE ELECTROACOUSTIC KINESTHETIC SENSING (RAKS) SYSTEM
The RAKS system is an Arduino-based wireless sensor interface designed specifically for belly dance (Figure 1). "RAKS" references the Arabic term, *Raqs Sharqi* (Middle Eastern dance). The interface consists of a lightweight belt equipped with a LilyPad Arduino, XBee module, and an ADXL345 digital triple-axis accelerometer. The corset is equipped with a flex sensor. The RAKS communicates over the XBee 802.15.4 wireless protocol with a computer running Max [11].

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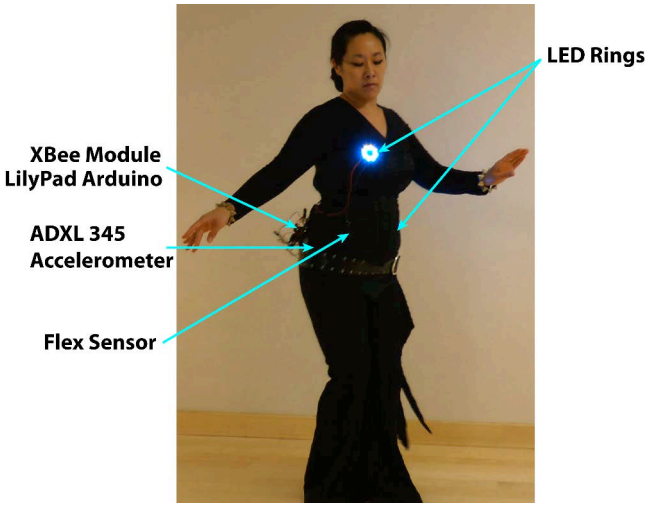

Figure 1. Performance with the RAKS system.

Gesture Attributes and RAKS System Design

The gesture attributes of belly dance movement influence the design and functionality of the RAKS system. Torso undulations, controlled hip isolations, and upper and lower body layering are a few characteristics of the movement vocabulary. To this end, the flex sensor is placed near the chest and torso, and the accelerometer is placed on the hips to optimize movement capture. Table 1 summarizes the gesture attributes and corresponding sensors. As terminology for belly dance movement is not standardized, the term "vocabulary" refers to a general description of each type of movement.

Movement Vocabulary	Body Movement	Gesture Attributes	RAKS System Sensor(s)
undulation	torso	continuous, vertical, bi-directional	flex sensor
rotation	chest, hip	circular, horizontal	flex sensor
figure eight	torso, chest, hip	continuous, vertical, horizontal	flex sensor accelerometer
isolations	chest, hip	quick, slow, sharp, smooth	flex sensor accelerometer
layering	upper/lower body	smooth, sharp, isolated	flex sensor accelerometer

Table 1. Gesture attributes and RAKS system design.

MAPPING MOVEMENT AND MUSIC IN *TEKA-MORI*

Teka-Mori features an interactive relationship between movement and music by connecting choreographic gestures and sonic outcomes. The piece conveys a dystopian, "broken-machine" aesthetic through noisy, distorted sonic material. Instead of focusing on the control of a single musical parameter (e.g. pitch), mapping strategies are modeled on the relationship between playing techniques and acoustic instruments. As more energy is transferred to an acoustic sound source, timbral variation increases. For example, increasing bow pressure on a string instrument results in a more complex audible frequency spectrum.

Contraction and Release: Bow Pressure

Teka-Mori begins with the dancer controlling a physical model of a bowed bar [15]. The flex sensor is mapped to the bow pressure parameter. The dancer's torso movements, including body waves and a side-to-side figure eight motion, increase and decrease the bow pressure of the physical model. This links physical and virtual gestures, establishing a one-to-one relationship between torso movement and variations in timbre.

Curving and Straightening: Modulating Waveshape

The Chebyshev waveshaping module features two points of control: the accelerometer's X-axis and the flex sensor control the mid and end points of a Bezier curve respectively. This curve controls amplitudes of even harmonics of the first twelve partials. Lateral hip circles modulate mid-range frequencies, and reverse body waves modulate high frequencies.

Accelerating and Decelerating: Pulses to Pitch

In the pulse train module, the X-axis of the accelerometer controls pulse interval and the flex sensor controls a low pass filter. At frequencies below 20Hz, the pulses sound percussive, and at higher frequencies these percussive streams begin to sound pitched. Lateral figure eight movement in the hips, punctuated by pauses, controls whether the module produces pitches or pulses. Slow side bends in the torso change the center frequency of a low pass filter. The combination of these slow, controlled movements simultaneously control pitch, rhythm, and timbre.

Movement and Stillness: Oscillators

The oscillator bank module maps acceleration in the dancer's movement to sound. The flex sensor controls the lowest frequency of an interpolating oscillator bank. The rate of change of the accelerometer's Y-axis produces increasingly higher partials, thus greater movement produces an increase in high frequency activity. In this module, the choreography consists of a combination of slow and rapid turn sequences punctuated by pauses in the movement. When the dancer is turning, the oscillator bank produces a cascade of sine waves up to a high partial determined by the level of movement. When the dancer pauses, these upper partials disappear, leaving only the lowest frequency. The output signal from this module is delayed, producing a sonic echo of the dancer's movement.

FUTURE DEVELOPMENT

Future development of the RAKS system will include enhancing capabilities for bi-directional improvisation in performance, adding biosensors and haptic feedback, as well as developing a network of multiple systems that will allow data to be shared and mapped between different performers. We will continue our work with the drum solo form and construct additional software modules that incorporate interactive control of physical models. We also plan to explore mapping strategies based on machine learning.

CONCLUSION

A kinesonic approach to mapping movement to music foregrounds an embodied perspective. The RAKS system, designed around belly dance movement vocabulary, integrates movement, kinesthetic response, and sonic elements. Based on the relationship between playing techniques and acoustic instruments, both standard and complex mappings are used to correlate movement and music within this kinesonic framework.

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