The design of technological interfaces for interactions between music, dance and garment movements

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ABSTRACT
The present work explores the design of multimodal interfaces that capture hand gestures and promote interactions between dance, music and wearable technologic garment. We aim at studying the design strategies used to interface music to other domains of the performance, in special, the application of wearable technologies into music performances. The project describes the development of the music and wearable interfaces, which comprise a hand interface and a mechanical actuator attached to the dancer's dress. The performance resulted from the study is inspired in the butoh dances and attempts to add a technological poetic as music-dance-wearable interactions to the traditional dialogue between dance and music.

Author Keywords
Wearable technology, musical interface, performance, mechanical actuators.

CCS Concepts
• **Human-centered computing** → **Sound-based input / output**; • **Applied computing** → Performing arts; • **Hardware** → *Sensors and actuators*;

1. INTRODUCTION
The design of music interfaces is not entirely related to what produces sounds. In fact, most of the musical interfaces designed for music performances explore musical ideas related to other domains of the experience such as haptics and visuals. In addition, music interfaces are often presented in rich multimodal contexts such as live concerts, installations, video, soundtracks, dance and theater. These interfaces seem to facilitate the attachment of musical poetics into wide relationships between gestures, dance, art visuals, light, novelty, re-invention and experimentalism.

There is nothing new about that. For centuries, traditional cultures all over the world have being performing relationships between music, movement, interfaces, objects, poetry, in many ways. Musical cultures often rely on the materiality of objects (musical or not) that interface human actions with members of the community, with sound, rituals or image [8, 12]. How do we cope with the multiple possibilities in the design of computer music interfaces that are not only musical?

In this work, we describe and discuss a set of multimodal interfaces that capture hand gestures and promote interactions between dance, music and wearable actuators as a strategy to expand the design of the musical interface to other domains of the performance. The attention is on the choreographical body, or how poetical relationships are created between sound, hand gestures and mechanical actuators working close to the skin. Our aim is to study the relationships between wearable mechanics, cloth design, dance, music and musical gesture, by exploring this complex environment in the performance. From the scientific point of view, this work describes the technical and algorithmic elements necessary to implement mechanisms of control and mapping of sound and mechanical actuators in the attempt to enrich contemporary dance performances. From the musical point of view, this work studies how simultaneous gestures across agents and objects produce technological poetical elements for new music interfaces.

1.1 Concept
The set of interfaces is composed of a hand tracker, a computer audio system and a dress equipped with wearable interfaces that produce mechanical contractions and spins in response to the control, as represented in Fig. 1 and Fig 2. Two performers (agents) – a musician and a dancer – interact with the systems during the performance.

The choice for designing interfaces correlating gestures, music and wearable mechanics in a dance performance presents a particular controlling environment for dance: the dancer interacts with references that come from music and from movement stimuli inscribed in the cloth. As demonstrated in Fig. 1, the same gesture that controls music stimulus controls haptic and visual stimuli generated by wearable mechanics. As such, the dancer engages into a playful dialog with aural stimuli and sensitive mechanical movements on surface of her skin, whose patterns can be generated by a single hand gesture of the musician. The design of such specific poetical and technical environment suggests a number of questions and demand solutions that are not readily available in the literature. In special, the musical interaction with wearable electronics and mechanical actuators placed on the body of the dancer represents technical and conceptual challenges that produce unusual technological poetics. These elements will be discussed in following sections.

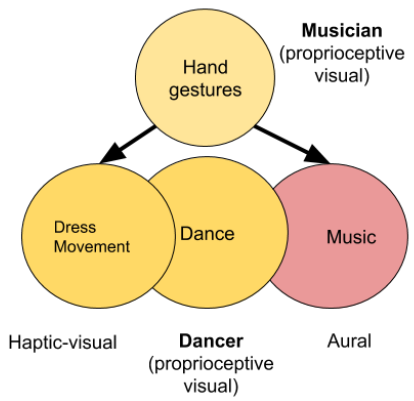

Figure 1. Schematic representation of the interfaces, agents (musician and dancer) and sensory categories engaged in the proposal.

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1.2 Wearable Technology as technological poetics

Wearable technologies are widely used by engineers, artists, fashion stylists and musicians to produce technological instruments or objects that can be worn or ported on the body. Its origins come from wearable computing, which encompasses an extensive range of objects, materials and methods that enhance sensory-body experience in relation to an object or into space in general and can be extended to a number of musical interfaces proposed in the last years (see an extensive discussion on the topic in [15]). The increasing number of wearable products present in our daily lives also help artists to experiment with new ideas to investigate social questions in the form of art proposals and to dissolve disciplinary divisions, as Machado argue:

> In recent years, the suspicion that the frontiers, so categorically traced back in the previous century between art, science and technology, is no longer being maintained with the same vigor, is becoming widespread in various fields of knowledge [16].

The dissolution of these frontiers, the approximation between art and science, the subversion of technological environments, the generation of fruition as a technological product, all contribute to new "technological poetics" narratives[16]. Besides developing new technological objects and technologies, the artists engaged in this field explore new cultural relationships conceived by the technology. Indeed, art is an effective "probe" the limits of technical means up to the frontiers of fantasy and unimaginable, which then can be used to refeed technology with new concepts.

Jones [9] states that "the only way to produce a techno-cultural debate on the speed of technological innovations is to put these technologies at the service of aesthetics." Jones completes: "aesthetic practices," that is, artistic activities, "locate how bodies are interacting with technology in the present moment, and even question those places." The aesthetic experience produced by technological means is another example of technological poetic. From this viewpoint, art could be seen as a way of subverting the technology itself and its purpose.

In the music field, the development and use of wearable devices in computer music approaches was initially blurred by the idea of "musical instrument" that accompanies the workflow of music production. Musical instruments such as the well-known Michel Waisvisz's "The Hands" [21] and the Expressive Footwear [18] where presented in the 1980s as expressive devices in relation to their artistic, although they do not explicitly referred to their wearable structures. More recently, Chi-Hsia Lai and Koray Tahiroğlu [14], used what they call wearable technology to amplify the sound created by the performer's actions such as scraping and tapping. Giuseppe Torre et al [22] developed a kind of wristlet which contains sensors with accelerometers, gyroscopes and magnetometers. The data collected by these electronic components is sent by wireless to be computer processed. The result shows a video and audio mapping of the perform at real time allowing the choreographer or artists to work with this real-time information.

Another interesting use of wearables was made by Kirsty Beilharz et al. [3]. Kirsty and colleagues used a microphone, a light sensor and multi-dimensional gyroscopic sensor aiming to capture physical features of an environment surrounding a person. The response was obtained in form of noise by a sound speaker or by fabric movements using a muscle wire (a metallic alloy that changes shape when current is applied). Their concept of what is a wearable stand out for its concern to create a fashionable object, which brings the cultural aspects of fashion design into the design of wearable interfaces, such as the notion of intimacy of the garment or the presence of clothes in the daily life.

The basic classes of electronic components used by these proposals involve microcontroller, sensors and actuators. Since the wearable context imposes challenges of portability and mobility, wireless protocols and portable sources of energy are of great importance. For this reason, the idea of the Internet of Things (IoT) comes aligned with wearable computing and promotes the protocols and accessibility that allows these objects to be controlled remotely or accessed as service providers [20].

In the present work, we combine sciences, engineering, art and music as a form of "epistemic stress": the dancer responds to unusual sources of interaction; interfaces are adapted to sense and produce movement by wireless protocols and the movement of the musician interferes in music and movement processes. The process of mutual integration that takes part in the application of different areas of knowledge is described in the next sections.

1.3 Overview of the project

The set of interfaces proposed in this work involve (1) a hand tracker, (2) a computer audio system and a (3) dress equipped with wearable interfaces. The hand tracker uses an implementation of objects for Pure Data platform object that collects information of the hands from of a Leap Motion [1] hardware. This information is processed in Pure Data [19] and used to trigger both (1) music in a computer workstation but also (2) mechanical actuators in the wearable interface. The wearable interface consists of a dress equipped with micro Servo motors, controlled by a microcontroller, that is complemented by an electronic circuit and battery embedded into the piece. The performance was developed as a contemporary dance performance, whose improvisation is loosely inspired in the butoh dance. Music and wearable movements channel the interactions between musician and dancer. Figure 2 describes a schematic overview of the system.

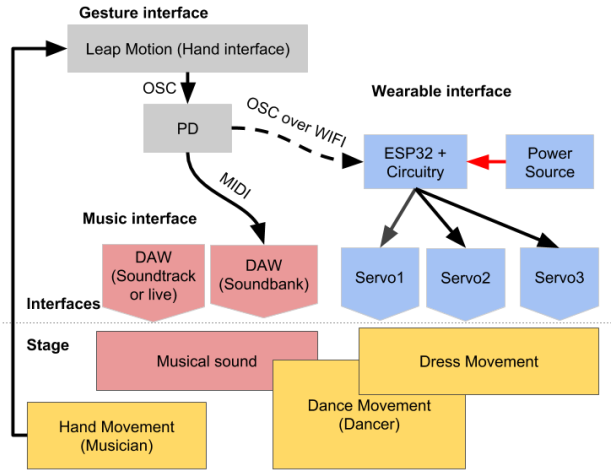

Figure 2. Schematic diagram of the interfaces, internal systems and components and stage elements. Red blocks represent the structure of musical interfaces. Blue blocks represent mechanical interfaces. Yellow blocks represent elements that involve movement.

2. TECHNOLOGICAL INTERFACES

2.1 Gesture interface: hands

The gesture interface captures the interaction of the musician, who uses two hands to trigger sounds and wearable mechanics embedded in the dancer's dress. The hardware interface uses an implementation of a Pure Data [19] object that extracts tracking

information from the Leap Motion device, realized by Chikashi Miyama[1]. More specifically, information of the hands, finger positions and angles are used to create a vocabulary of gestural control. As expected, the process of the creation of relationships between gestures and sound/movement is interactive and empirical. Hand gestures were also though as possible visual references for the performance in the sense that processed images or "shadows" of the hands could be used.

2.1.1 Data processing

The management of complexity is an important issue in projects that the interaction between different modalities is the core element of the performance. Expecting the escalation of combinatory possibilities, we designed the sound and movement control as simple, but meaningful controlling strategies. Meaningful, here conveys processes that exhibit perceivable relationships between modalities and allows virtuosity and exploration of improvisation in the performance [as discussed, for example, in 4]. Sound textures were produced by a DAW software using state-of-the-art samples and sound processing effects. A set of controlling routines were implemented in order to control the sound texture, described as follows:

Relationships from Gesture (Hand) to Music:

- Fast movements of the hand trigger a midi (note on) note executed from a random interval jump, selected from within a range of interval (positive and negative). Empirical trigger thresholds are applied to velocity curves.
- The range of the interval jumps is controlled by the distance (Euclidean distance) between the position of the thumb and the little finger in the Euclidean space.
- The vertical position of the hands in relation to the interface controls the positive (higher) or negative (lower) tendency of pitch interval jumps (thus controlling tessiture).
- Fast downward hand movements lower the pitches to a minimum.

Relationships from Gesture (Hand) to Wearable mechanics:

- The distances between the two hands control the twist of the 1st frontal servo.
- A turn of the right-hand twists the 2nd servo positioned at the back, proportionally.

As seen above, the relationships are independent but can be combined in whole gestures (e.g.: shaking the hand while increasing the distance between two hands), which provides a combinatorial vocabulary of interaction and space for exploratory play.

2.2 Wearable interface

The wearable interface consists of a dress equipped with micro Servo motors, controlled by a microcontroller. The device is also supported by additional electronic circuits and battery embedded into the dress.

This cloth interface, besides dressing the dancer, is a proof of concept of wearable technologies applied to a dress. The embedded technologies used in this project explores this concept in relation the performance, which represents a different proposition from the industries' wearable design. The performer had to feel and adjust dance movements considering the twists of the servo motors on the fabric's dress. Although the relationship created between music, dancer and dress drives the poetical concept in performance, they are intrinsically dependent on the empirical and technical connections between gestures, electronics, mechanics, fashion design.

The main element of the wearable technology dress is the microcontroller. We opted to use the Expressif ESP32 microcontroller due to its widespread use in robust applications [7]. The OSC protocol was used to establish the communication between the computer and the ESP32. The control information was produced by the gestures captured by the Leap Motion, as illustrated in Figure 2. The code used in the microcontroller was developed in the Arduino IDE and it is available at https://github.com/nlamounier/wearable-tech-reversa.

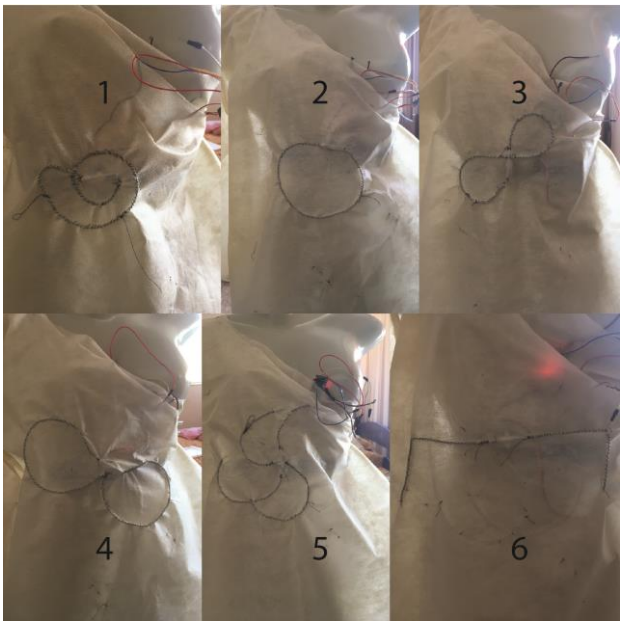

Figure 3. Test structures with the Servo Motor. Structure 1: spiral, structure 2: circle, structure 3: Möbius small, structure 4: Möbius large, structure 5: radial, structure 6: line.

In order to produce movements on the fabric, we opted to use servo motors as mechanical actuators. After a number of tests with electric muscles and other motors we understood that the small size, availability and weight [7] of simple 9g servos, offered the best compromise between portability, implementation and range of mechanical movements.

The servo motors were allocated in the region of the thorax because since this body position is more stable during body movements. We performed tests with six different mechanical structures attached to the Servo motor (Fig. 3) in order to evaluate possible twist patterns in the surface of the fabric and how they could fit into de elements of the performance. We opted to work with radial circular structures (frame 5, figure 3) since they provide "organic" movements in the surface of the dress.

In order to integrate the motors and circuits to the dress we had to design a modular structure that allows easy and fast withdraws of the electronic components. This procedure was necessary in order to connect the ESP32 with the computer, to make a rapid change of a device (if necessary), and to provide basic maintenance. Therefore, the circuit was assembled on a firm and thick elastic belt with fittings that can be adjusted to three different levels (Fig. 4).

Although the use of wearable electronics in music and dance performances are not new, the setups necessary to embed electronics into the cloth and performance objects are very specific. As a systemic arrangement of modalities, areas and skills, each component of the system influences the others. As such, the development of the project had to find empirical solutions for the problems for the communication

[1] https://github.com/chikashimiyama/Pd_leapmotion

between agents and composers to flow as a collective authoring of the technological poetics.

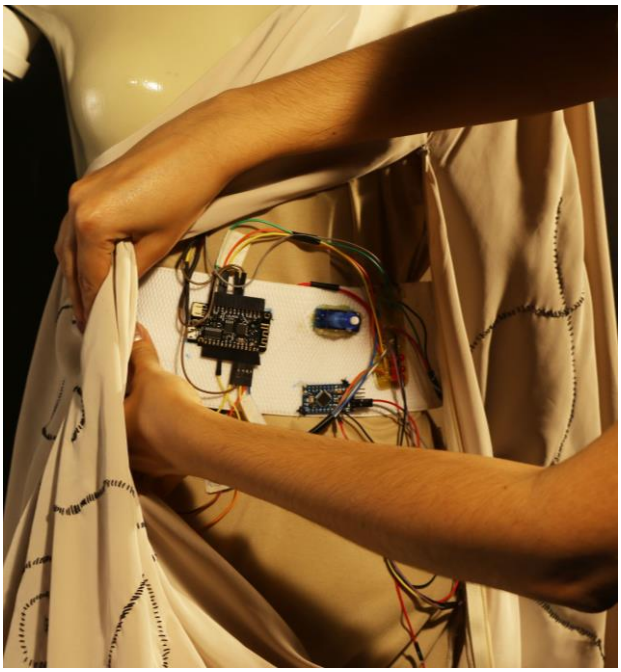

Figure 4. Assembly of the belt with the circuit inside the dress.

3. DEVELOPMENT AND STRUCTURE OF THE PERFORMANCE

The performance was developed as a contemporary dance performance, whose improvisation is loosely inspired in the butoh dance. From a Western cultural perspective, the butoh can be seen as a dance improvisation method, a dance form, or a meditative practice among others more or less effective definitions [2, 6, 10, 17]. It emerged in the late 1950s in Japan, developed by Tatsumi Hijikata and continues to be highly influential among dancers and movement of contemporary dance [11]. Apart from the problematic task of defining butoh, two elements of this practice became essential for this proposal. First, the expressive elements of butoh are characterized by minimalistic actions (as seen from a Western artistic perspective), which helps to study the performative role of the tiny changes in the surface of the dress and to manage time and synchronization across the complex interaction between sound and mechanical devices. Second, butoh might be seen as a self-reflective practice and not exactly as a form of expressionistic dance [11], which places the dancer at the center of an environment where the choreography is developed from the reflexive interpretation of sound and haptic stimuli. We used these two conceptual elements – minimalism and self-reflexion – as a guide to solve technical and poetical challenges.

The structure of the performance followed the original butoh music and aesthetic. The basis of the performance is a musical composition structured in 4 sections: (1) presentation (dancer in free improvisation), (2) insistence (dancer in tension), (3) first solo (hands control dancer), (4) solo B (dancer alone or music follows dancer) and (5) duo (without hierarchies). The tessiture were composed of a layer of chords that can be played by any plucked polyphonic instrument, sampler, synthesizer or audio playback. An improvisation layer was played by means of samples attached the patterns of movement captured by the hand interface, following the interactive logic described in section 2.1). In the performance, the layer of chords was sequenced in a DAW interface (Apple Logic) using state-of-the-art samples of plucked instruments and effects (reverbs, equalizers and compressors) in order to prepare the sound addressing elements for a public performance. The plucked timbre offers an approximation of the oriental or Japanese elements to help establish a better understanding of cultural attachment of butoh dances.

The performance is guided by the improvisation of the agents - musician and dancer – in relation to the musical structure. In the choreography, the dancer is instructed to follow the structural elements described and to focus on the self-reflexive impact of patterns, suggested by sound and haptic sensations generated by the wearable device.

The dress itself represents another element that interacts and influences the dance movements. It was essential to do rehearsals with the interfaces in order to provide the dancer with conditions to recognize and interact with the range of the stimuli generated by the wearable elements of the dress. During the rehearsals, it was tested and exploited the garments' movements in order to increase the poetical power of performance. It was essential to experiment the engines as an important component in the assimilation of the mechanical elements by the dancer. In this way, the performance was enriched also by the performer's contribution, who played an important role. The dancer feedbacks were noted and taken into consideration.

In addition to analyzing the overall performance of the interfaces, the rehearsals were also crucial for testing the electronic components on the belt and the engine rods sewn on the cloth. The battery was also an important focus point, as it should feed the electronic compounds during the entire performance.

4. THE PERFORMANCE

The performance[2] was recorded with two cameras and stage light equipment that helped to make the effect of the contortions of the dress more visible by improving the contrast of light and shadows. The hands' gestures of the music performer were projected on the wall (Fig. 5), which provided an augmented source of references to understand the connection between the elements of the performance. Besides the hand movements that create the music and activated the servos engines, their projection played an aesthetic role on the performance. The projected hands seem to communicate with the dancer, whilst the musician's hands really do by creating the movements that were translated to the garments' motors and therefore to the performer.

The integration of small and minimalistic movements across dance and mechanical actuators seems to be coherent with the visual and temporal aesthetics borrowed from the butoh dance. Coherence, in this case, is reflected by an augmented tension that drives the audience's gaze to explore minimal interactions and micro-movements. Pauses, solos, accidental synchronizations and repetition of patterns are some of the artifacts used in both musical and dance elements.

Technically, the robustness of the structures comprising the belt, ESP32 and the circuits could provide hours of successful testing and seamless performances due to its simple design and low energy consumption. Although power source was always thought as an issue due to the demands of the servo motors, these components were not always moving, which provide only peaks of consumption but fairly good power consumption for hours of performance. The same robustness was seen in wireless data

[2] https://youtu.be/GEkl8qdTBLQ

communication between the ESP32 and OSC and connections with electric cables. Far from superficial technical observations, the feasibility of running such interfaces for hours opens new possibilities for wearable technologic objects and poetics.

Figure 5. A frame of the video demonstrating the dancer performing with the garment, the shadow of the hand interface.

5. FINAL CONSIDERATIONS

This study shows one point of view over the chain of possibilities promoted by the links between technology and music interfaces. By considering the prior connections between music and other elements of the performance, the design of interactions and poetical possibilities could breathe through less dense interactions, such as the one presented, as a form to guide the audience attention to the poetical elements shifting from music, dance and movements.

We may have taken a so-called "transdisciplinary perspective" [5] in the sense that we understood the performance and its modalities as a whole question and promoted interactions between each area of knowledge-oriented by the conceptual problem of integrating media. On the other side, we could have simply integrated disciplines without thinking the performance as a whole. The first perspective leads to many issues including authoring (who created?), definition of the forms (what is the music or the dance?) and definition of expressive structure (what is being expressed?). This configuration, as mentioned before, resemble the issues of interpreting traditional art/cultural forms in traditional cultures where authoring, art form and expression are not so clear as in Western art.

Regarding the wearable interface, the study has shown that the complexity encoded in the interaction between microcontrollers, servo motors, electronic circuits, motion capture interfaces and protocols can be reduced to an integrated poetical environment. The systems are mature and can be used invisibly across clothes, musical instruments and spaces. Moreover, the wearable electronic approach in a form of a poetical structure added technology to the dance performance without changing its main visual aspects.

The elements of the performance somewhat subverted traditional flows of sensorial information in dance performance in an uncommon way: instead of producing unperceived dress movements that were traditionally generated by dance movements, that dancer had to perceive and react to movements of the dress, produced by the music and gesture interactions.

For future works, we will explore issues regarding the movements of fabric as well other mechanical actuators that could improve the ideas for the wearable dress. More complexity in the system could be also studied by looking at interactions with sensors placed in the dress, and the use of artificial agents interacting with controls and visuals. These explorations could improve and provide other potential ways of thinking about poetic technologic interfaces for music and new concepts for wearable devices for music and industry.

6. ACKNOWLEDGMENTS

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