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Embodied Music Interaction: Creative Design Synergies Between Music Performance and HCI

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Abstract

In music performance, a range of novel digital musical interfaces (DMIs) has been explored that share both real-time and musical interaction. This chapter draws on the theoretical strand in the human-computer interaction (HCI) of *embodied interaction*, a conceptual approach that is helpful for designing novel physical interactions and experiences. This chapter compares the design characteristics of tangible, mobile, wearable, gesture sensor-based, and laptop-based interaction from an *embodied music interaction* perspective, in which *shareability*, *digital-physical coupling*, *materiality,* and *situatedness* are important design aspects for music performance. This approach can be helpful for identifying the limitations of existing designs and potential new areas for development.

Introduction

The multidisciplinary field of sound and music computing (SMC) offers the opportunity to combine scientific, artistic, and technical skills with the aim of building new computational tools and applications for understanding, manipulating, and generating sound and music (Serra et al., 2007). Particularly within music performance, a range of novel *Digital Musical Instruments* (DMIs) (Miranda and Wanderley, 2006), *Digital Musical Interactions* (DMIs) (Gurevich and Cavan Fyans, 2011), and *New Interfaces for Musical Expression* (NIMEs) (Fels, 2004) has been explored that share a common nature based on real-time musical interaction but characterized as being highly computationally demanding. It is thus argued that designing technologies for a music performance space can inform technology design in other artistic domains (Buxton, 1997).

In DMIs for music performance, there is a modular distinction between the element of control (e.g., the input device or gesture controller) and the element of sound generation. This contrasts with acoustic musical instruments, in which both elements are coupled (Jordà, 2005). The currently available technologies offer a number of human-computer interaction choices, including *tangible*, *mobile*, *wearable*, *gesture sensor-based*, and *laptop-based*. The role of the performer's body is a key aspect in a real-time dialog with the control of the DMI. In the words of Chadabe, "the computer responds to the performer and the performer reacts to the computer, and the music takes its form through the mutually influential, interactive relationship" (Chadabe, 1984: 23). To the best of our knowledge, little has been studied about comparing the role of the body when using different DMIs for music performance and the implications for a DMI design. This chapter aims to fill this gap. Such a discussion of DMI systems can help to improve the understanding of DMIs from a human-computer interaction (HCI) perspective and enrich conversations on the subject to also assist identifying new directions of interdisciplinary research. Moreover, it can help practitioners to think more broadly about embodied musical interaction during the process of a DMI design.

Embodied Interaction in HCI

This chapter draws on the theoretical strand of embodied interaction (Dourish, 2001) and on HCI's third wave (Bødker, 2006), and is a follow-up of Jewitt et al. (2016)'s work. The third wave in HCI applies research methods from both social sciences and the arts for understanding complex interactions with digital technologies. *Embodied interaction* refers to a conceptual approach for understanding the novel physical interactions and experiences that new HCI systems afford. Dourish (2001) emphasizes how meaning is co-constructed through making within a social context and is mediated by the technology used. Embodied interaction is connected to the philosophical stance of embodiment and phenomenology, particularly the philosophies espoused by Heidegger and Merleau-Ponty, and the notion of being in the world, and perceiving with, and learning from, our bodily actions, within a social and cultural practice.

This chapter explores the challenges and potentials of embodied interaction using DMIs for music performance, referred to here as *embodied music interaction*. Using a theoretical framework of HCI is helpful for understanding these phenomena. How the fields of HCI and NIME mutually inform each other has already been researched (Buxton, 1997; Holland et al., 2013; Jordà, 2008); however, there is little research on the role of the body in DMIs, an area to which this chapter contributes. Inspired by a quote by jewelry designer Art Smith, one can say that the body is an important aspect in music technology design, just like melody, harmony, rhythm, dynamics, and timbre.

> *A piece of jewelry is in a sense an object that is not complete in itself. Jewelry is a 'what is it?' until you relate it to the body. The body is a component in design just as air and space are. Like line, form, and color, the body is a material to work with. It is one of the basic inspirations in creating form.*
>
> –Art Smith, 1969

Digital Musical Instruments

This section presents the characteristics and some examples of different interaction approaches to DMI design: *tangible*, *mobile*, *wearable*, *gesture sensor-based*, and *laptop-based* interactions. The selection of examples is illustrative rather than extensive. In the early 1990s, Weiser (1991) coined the term *ubiquitous computing* (ubicomp) to refer to technologies in which the computer is less visible during the human-computer interaction (e.g., in wireless, embedded, tangible, wearable, distributed, networked, and/or mobile technologies).

Tangible Interactions

Tangible interactions take place through tangible user interfaces. The term *tangible user interfaces* (TUIs) refers to physical objects that can both control and represent digital information. Pure touch interactions are also included in this category. With TUIs, there is a *direct interaction*, which allows users to directly manipulate the digital information. An early example of a musical TUI is the *Squeezables* (Weinberg and Gan, 2001), a set of six squeezable balls that can be controlled by continuous squeezing and pulling hand gestures. Tabletop TUIs are table-based systems that enrich the experience of a table with computing. For example, *SoundXY4* is a tabletop system for music performance with a tangible multi-user interface developed by the author (Xambó et al., 2014). Inspired by the *Reactable* (Jordà, 2008), the system includes cubes that trigger sounds, and cubes that apply effects on the sounds (see Figure 1).[1]

Figure 1. *SoundXY4, a tangible musical interface*.

Mobile Interactions

Mobile interactions refer to the use of mobile devices, while *mobile music* refers to music creation with these devices. For example, Tanaka (2004) explores how collaborative musical creations can be performed in mobile and remote conditions with users connected to the same network. There are also examples of co-located settings with ensembles such as the *Michigan Mobile Phone Ensemble* (Essl, 2010). These ensembles offer a number of performances that experiment with the possibilities of the mobile medium using mobile devices and laptops (see the section: Laptop-based interactions). Furthermore, Lee and Freeman (2013) explored the notion of the audience as performers by creating a musical performance for large-scale audience participation using networked smartphones. Mobile devices facilitate an exploration of different concert settings. Gesture-based and whole-body interactions have also been explored in mobile music (Roma et al. 2017).

Wearable Interactions

Wearable interactions involve the use of wearables. A *wearable* refers to a body-worn computer or device that is designed for particular functions (Starner, 2014). We here focus on wearables for music creation. For example, *Gangsta Headbang* is a demo of a wearable developed by Gerard Roma and the author (see Figure 2). Here, a fedora hat triggers chords when following the rhythm with your head using *embedded electronics*.[2] Wearable computing also includes the exploration of *e-textiles*, which combine embedded electronics with textiles, or new fabrics or materials. For example, *smart material interfaces* (SMIs) investigate new materials that can change their properties (e.g., color, shape, or texture) under external stimuli (e.g., electricity, magnetism, light, pressure, or temperature) (Minuto et al., 2012). In SMIs, the material integrates both the input and the output as part of the physical object and interaction.

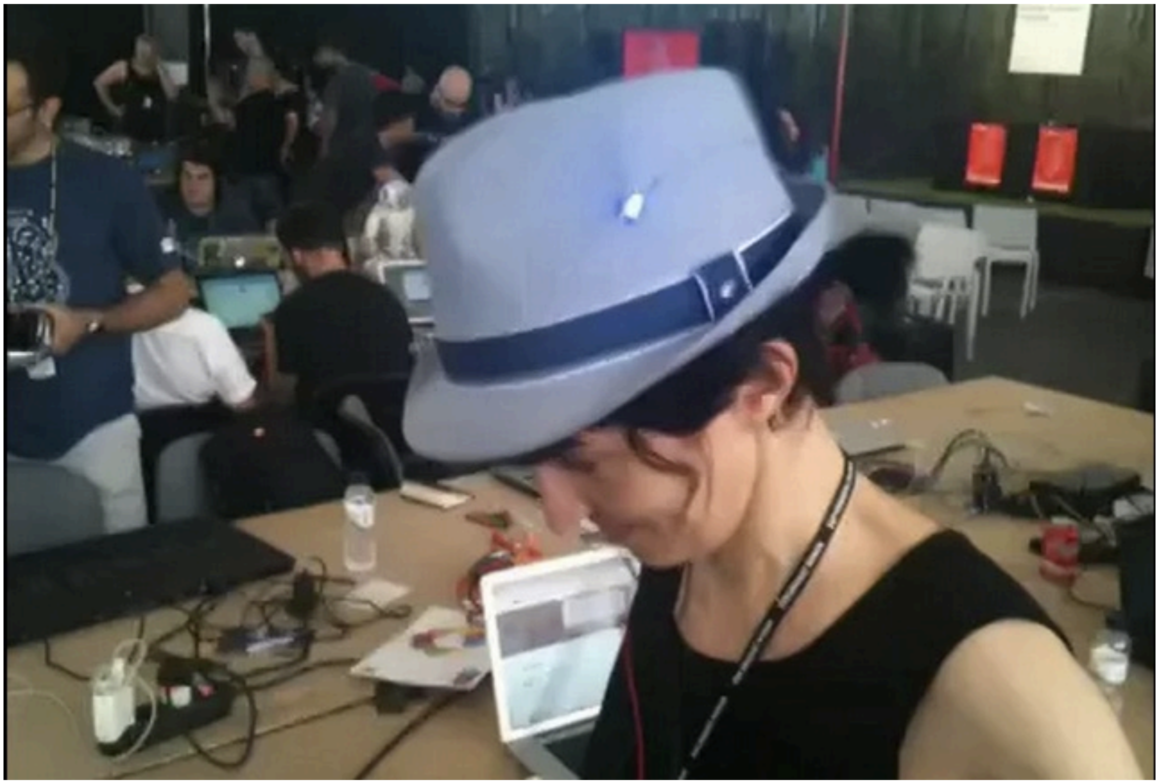


Figure 2. *Gangsta Headbang, a wearable that augments a fedora hat presented at the Music Hack Day (Sónar Festival 2015, Barcelona, Spain).*

Gesture Sensor-based Interactions

Gesture sensor-based interactions refer to interactions with the interface based on gestures. There exist a number of examples of gesture sensor-based interactions: The group *Sensorband* performed computer music by using a range of gesture-based sensors (e.g., ultrasound, infrared (IR), and bioelectric sensors) (Bongers, 1998). In the *Harmony Space* system, harmony (e.g., bass notes or chords) can be explored using the whole body by stepping on the floor-projected interface (Holland et al., 2009). These examples show how collaborative music can be performed by means of interconnected bodily gestures.

However, there is little mention of the social aspects of these bodily interactions, which is of interest in this chapter.

Laptop-based Interactions

Laptop-based interactions refer to interactions using laptops. There exist a number of laptop ensembles and orchestras all over the world.[3] Some of them explore egalitarian approaches to the ensemble, while others explore more hierarchical structures. The *Stanford Laptop Orchestra* (SLOrk), directed by Ge Wang (Wang et al., 2009), was founded in 2008. Usually involving more than 20 laptops, the performers also use controllers and custom speakers. *The Republic* is a project that started in 2003 based on collaborative *live coding* involving a number of performers (de Campo, 2014). Live coding practices are based on the use of scripting languages for real-time music improvisation (Collins et al., 2007). The Republic's principle is to create a symmetrical network, in which each player can access and modify each other's code. However, despite the increase in performances and their potential in collaborative music using DMIs, a major criticism of laptop-based performances is the lack of transparency of the performer's actions.

Embodied Music Interaction

This section investigates how HCI can help us to understand embodied music interaction during practice and performance using an adapted conceptual framework of embodied interaction. It focuses on the role of the body using DMIs for music performance. The most meaningful categories of embodied music interaction include: *body*, *materiality*, *input control*, *sound output*, *coupling physical-digital*, *visibility/feedback*, *shareability*, and *situatedness*. Figure 3 summarizes these categories by comparing the tangible, mobile, wearable, gesture sensor-based, and laptop-based DMIs.

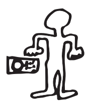
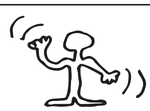
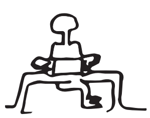
DMI	Body	Materiality	Input Control	Sound Output	Coupling Physical-Digital	Visibility/ Feedback	Shareability	Situatedness
 Tangible	Hands, upper body	Physical objects, tabletop surface	TUIs, multitouch surface	Embedded or detached	Seamless coupling	Body-scale level (group), audio/visual/ haptic feedback	A shared interface, multiple tangible objects, multitouch interaction	Individuals or groups
 Mobile	Hands, upper body	Physical device, screen	Sensors (e.g., accelerometer, camera, gyroscope, magnetometer, mic, multitouch screen)	Embedded or detached	Seamless coupling	Hand-scale level (individual), audio/visual/ haptic feedback	Individual interface or multiple individual interfaces interconnected on a network	Individuals or groups
 Wearable	Full body	Physical wearable (e.g., textile, garment, material)	Sensors (e.g., accelerometer, biosignal, gyroscope, magnetometer, photodetector, pressure, temperature, touch)	Embedded or detached	Seamless coupling	Body-scale level (group), audio/visual/ haptic feedback	Individual interface or multiple individual interfaces interconnected on a network	Individuals or groups
 Gesture	Full body	N/A	Sensors (e.g., biosignal, IR, ultrasonic)	Detached	N/A	Body-scale level (group), audio/visual/ haptic feedback	Individual interface or multiple individual interfaces interconnected on a network	Individuals or groups
 Laptop	Hands	Physical device, screen	Sensors (e.g., camera, light, mic, touchpad), computer hardware (e.g., keyboard, mouse)	Embedded or detached	Seamless coupling	Hand-scale level (individual), audio/visual/ haptic feedback	Individual interface or multiple individual interfaces interconnected on a network	Individuals or groups

Figure 3. *Categories of embodied music interaction.*

Body

Body refers here to the parts of the body that are needed for interacting with the DMI. For instance, hands are used by laptop-based, mobile, and tangible DMIs. However, in tangible and mobile interactions, other parts of the body can also be used, such as the upper body. The full body is particularly used in body-worn interfaces, such as wearables or gesture sensor-based interfaces. This is related to the category of *Range* within Bert Bongers' taxonomy for physical interface design (Bongers, 2006), which refers to the space of influence from a human scale perspective, including: *within the hand*, *within the reach of the arm* or *within the architectural space*. According to Bongers (2006), operating with hands is related to interfaces on a more intimate scale, as opposed to interfaces on the architectural scale, where body movement is spatially more noticeable. However, Bongers’ taxonomy focuses on the movement during physical interaction, as opposed to embodied interaction, in which the bodily actions are also associated to a social and cultural environment. The social is more present in bodily interactions with DMIs that can be more easily seen (e.g., TUIs, wearables, gesture sensor-based), or that invite multiple users to participate (e.g., TUIs, mobiles), even though they can operate in the intimate space too (e.g., mobiles).

Materiality

Materiality is related to the physicality of the interface and the involvement of the body during the interaction. Physical objects are used in TUIs and wearables, combined with touch in e.g., tabletop TUIs. Touch screens are used in mobile devices, laptops and multitouch tables. Typically, gesture-based interfaces lack materiality. In the domain of *tangible music*, there are considerable differences between using a pure touch interface versus using a physical tangible interface. Touch input involves the finger manipulation of digital objects, whereas a tangible input involves the manipulation of physical objects. Both cases use haptic information related to human tactile feedback. However, the user perceives the information about the object in a different way, because with tangible manipulation, the world is perceived through tools (i.e., tangible objects), which contrasts with the abstract digital representation when using pure touch on a screen. This resonates with Gibson's (1966) notion of haptic perception as an active exploration, and the different perceptual experiences between using the body to explore the world and using a tool as an extension of the body to explore the world. When using a tool, there are haptic characteristics, such as size, temperature, texture, volume, shape, or weight, which enrich the haptic experience. Since the popularization of touch-based devices, such as smartphones and tablets, users are familiar with both types of interaction. However, we argue that with tangible input, the input style better resembles the interaction with physical musical instruments. Materiality is a salient characteristic of TUIs and wearables that may not be found in other ubicomp systems (Shaer and Hornecker, 2009).

Input Control

Input control refers to how the information is entered into the system. Keystrokes are commonly used in laptops; a range of sensors are used in gesture-based interfaces, wearables, laptops, and mobile devices; touch input is used in TUIs, mobile devices, laptops, and wearables; and tangible objects are used in TUIs and wearables. This connects to the notion of *degrees of freedom* of an input device, which refers to the availability of movements and orientations in a three-dimensional space (Bongers, 2006). Accordingly, the more movements that are tracked, the more complex the interaction. Thus, the complexity involved in a multitouch interaction with continuous data on tabletop TUIs, or in gesture sensor-based interactions, can provide a richer mapping between the body actions and the sounds produced, when compared to discrete keystrokes or continuous moves on the x and y axis with the mouse or touchpad in laptops. We argue that the richer the information on the body movements, the more interest from a live performance stance.

Sound Output

Sound output refers to how the sound information is delivered. From a ubicomp standpoint, it is expected to be a self-contained system, in which sound is embedded within the system. This implies typically the use of low quality, small size, and portable speakers. However, a number of DMIs allow for stereo or multichannel sound amplification, which implies a detachment of the sound output from the input control. Both embedded and detached approaches are used in TUIs, mobile devices, wearables, and laptops; whereas only the detached approach is generally used in gesture sensor-based interfaces. Arguably, the embedded approach is more consistent with the nature of ubicomp systems, as well as with acoustic musical instruments. By contrast, with an only detached approach, the sound output is the same irrespective of where the input control is produced, and gives an acceptable sound quality for performance. It is an open question as to how to amplify sound from a self-contained system to reach the quality expected in a performance, unless the acoustic properties from the embedded approach are actually sought instead.

Coupling Physical-Digital

Coupling physical-digital relates here to how smooth the coupling between the physical part and the digital part of a DMI is, where minimizing *latency* is important. *Seamless coupling* (Ishii and Ullmer, 1997) between the digital and physical, i.e., between representation and control, is an expected characteristic of TUIs, wearables, and other DMIs that use physical interfaces to control digital content. Tangible, mobile, wearable, and laptop-based interactions provide seamless coupling between the physical and the digital domains, of which TUIs and wearables include the use of physical materials as an additional layer of complexity. The lack of materiality of gesture sensor-based interfaces excludes them from this category.

Visibility, Clarity, and Feedback

Visibility and *clarity* relate to how performers' actions are seen and understood by other performers or the audience. The greater the human body scale used, the more visible and clear it will be for other group members and for the audience. It is an open question as to how to make visible to the audience individual-led interactions, such as laptop-based interactions, beyond just projecting the laptop's screen. Making visible the interfaces that are designed on a more intimate scale (e.g., mobile devices) it is recommended (e.g., using real-time video). *Feedback* refers to the system's mechanisms used to support the visibility and clarity of the performers' actions. In combination with auditory feedback, different senses can be used, such as visual and haptic. It is important to bear in mind the potential and limitations of the different senses; for example, visual feedback is commonly used, and so is probably expected. In tabletop TUIs, visual representations have been generally used as a mechanism to provide feedback about people's actions. Using the sense of touch is usually poorer than other senses, in terms of the visibility to others. However, as highlighted by Bongers (2006), touch provides information about how the interface feels, which is important in those DMIs in which materiality is relevant.

Shareability

Shareability refers to how suitable the DMI is to be shared. The fact that digital information can be contained in physical objects makes data more shareable, as a physical object is easily accessible to someone in its immediate vicinity (e.g., tangibles, wearables). Tabletop TUIs are based on a shared interface for multiple users. Interconnected devices, and therefore people with individual interfaces, are explored in mobile, gesture sensor-based, and laptop interactions. Wearables seem to be the most individual-led, although they can also adopt an interconnected-to-a-network approach.

Situatedness

Suchman (1987) introduced *situated action* as a term to describe the way users act in a particular context. Shared meanings are constructed according to the situation, which depends on the people involved and the particular technology used. *Situatedness* is related to constructing meanings either as an individual or as a group from using a particular DMI. Mobiles, wearables, gestures sensor-based interfaces, and laptops allow for both individual and group experiences, while TUIs are generally designed for multi-user interaction, yet individual experiences are also possible. Promoting both experiences also considering the audience is relevant here, which is a challenge in DMI design, where the design architecture can substantially change to support both individual and multi-user interaction.

Conclusion

This chapter has adapted the HCI theoretical framework of embodied interaction with the aim of informing the design of DMIs, which could be useful for both practitioners and researchers. Also, it has facilitated a greater understanding of DMIs to HCI researchers from a design perspective. The consideration of embodied interaction in DMI design can improve rethinking of the: 1) communication with the audience, and performers; 2) the shareability and collaborative features, allowing for scalability of the system; and 3) the materiality and space features, including connections between digital and physical spaces in the interface, and the space between and outside the practitioner and the musical instrument.

In summary, embodied interaction involves considering the role of the body, the social world, and the physical world, and indeed all three within a situated context. This can be applied creatively and fruitfully to music technology design, and could consequently inform back to HCI research. By analyzing embodied music interaction, we can shed light on better designing interfaces that require complex bodily interactions, which can in turn inform DMI design, and more broadly HCI design.

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[1] https://vimeo.com/70693984 (accessed February 28, 2016).
[2] https://vimeo.com/131216447 (accessed February 28, 2016).
[3] http://www.ialo.org/doku.php (accessed February 28, 2016).

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