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Approaches for Working with the Body in the Design of Electronic Music Performance Systems

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ABSTRACT
This article outlines a body-centred focus in the design of performance systems for electronic music. Through a movement-led design process, I discuss the interaction of the body, controllers, data and mapping. A flat hierarchy approach to performance system design aims to support bodily autonomy in performance, challenge human-machine dualism and expand the definition of virtuosity in performance to include system virtuosity. The affordances and behaviours of the components of performance systems are discussed in terms of their cooperation. With an awareness of the non-neutrality of data, controllers, and sensors, I outline methods for making adaptive and flexible systems which respond to and respect individual bodies. This embodied and hybrid approach to system design can facilitate posthuman expression in electronic music performance.

KEYWORDS
Electronic music performance; virtuosity; movement; body; embodiment; affordances

Introduction

In this article I discuss a movement-led design methodology for movement-based interactive performance systems in electronic music. In designing performance systems, I aim to promote a flat hierarchy, in which I am a component within the system rather than the controller of all elements of the system. The role of the body in my performance is positioned as an element not to be observed and assessed, but understood as a behaving component of the system. A flat hierarchy challenges the human-machine dualism prevalent in electronic music performance, and suggests a posthuman assemblage perspective which equally values the expression and cooperative behaviour of all components of the system. Following these discussions, I present some practical examples of how manual calibration within movement tracking can respond and adapt to individual bodies.

Approaches to Virtuosity

In an attempt to develop virtuosity in electronic music performance, my approach was to make as many of the elements within a performance system as I could. I wanted to

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understand how everything worked and I wanted to have full control over the entire process. This approach to the learning process proved useful when the goal was to achieve full understanding of the practice. I found that once a sufficient level of proficiency was reached, control could then be relinquished somewhat. This initial approach interprets virtuosity as simply precise control. My understanding and use of the term virtuosity has since developed beyond a traditional view of control and precision. Upon removing a need for control and ownership, I can instead begin to think of a system in which there are many component parts, of which I am one. This perspective allows me to challenge my own need for full control, while also allowing for the use of existing tools. This rethinking of virtuosity aligns with the views of many other musicians who use contemporary technologies, as documented by Kaiser (2018) where the interviewed musicians shared varying views on the subject of virtuosity. Kaiser even suggests many express anti-virtuosity views, 'to be a virtuoso in the traditional sense, for many interviewees, was not to express one's own identity, but to be defined by somebody else's identity and the imposition of these identities on the performer'. Other musicians, such as Robert Henke, had wished to redefine virtuosity as it can be applied to performers using certain technologies:

> there is a strong connection between the ideas you have and the virtuosity you have with your instrument … I judge virtuosity very high, rehearsing and practicing very high. You can become good at moving a fader … I have this specific haptic connection with those faders … This is why people like certain hardware, they are skilled at using it in a certain way … If you want to perform in a convincing way you have to react and this implies that you know your tools. (Henke in Kaiser 2018)

Henke's view still posits control as a key aspect of virtuosity and suggests that this kind of virtuosity is, from the musician's perspective, not externally validated by an audience. In an email conversation (February 2023), Henke added that although it is not important to him that the audience understands what he is doing, he believes that the audience perceive his virtuosity, seeing him being able to 'react precise and fast', and that they can 'feel the difference'. Henke's views and Kaiser's interviews show the complexity of the word virtuosity as it relates to electronic music.

The discussion from Couroux (2010) on virtuosity and anti-virtuosity relates to composer command and performers' precise realisation, despite it being contested whether or not the piece in discussion is even performable. This suggests a strive to push beyond human limitations in order to achieve a greater level of control. The notion that improvisation might be used where physically playing the material is not possible has been quickly dismissed, suggesting that this would not be perceived as virtuosic. In this discussion the roles of composer and performer are separated and it supports a more traditional view of the composer as authority. Godlovitch (1998) suggests primary causation is where skill lies. If we position virtuosity as an ability to facilitate through an embodied practice, not just a cognitive one, we can define virtuosity beyond precise control. Nicols (as quoted in Tonelli 2016) identifies her work as social virtuosity, and suggests that virtuosity can manifest through collaboration; 'you can sing with people who have never considered themselves a singer and create a social virtuosity, an amazing excellence of brilliance'. Considering virtuosity as something that results from a combination, opens the door to considering system virtuosity, where virtuosity results from the collaboration of component parts of a system.

Performance System Components

I have often focused on the question of whether I am aiding the computer in a performance or whether the computer is aiding me. This human-machine dualism has prompted me to deeply consider the affordances of a human performer and how the affordances contrast to those of a computer. As a result, when designing a performance, I try to assign the tasks appropriately. For example, if a high degree of precision is required for a task, then it might be assigned to the computer, whereas if imprecision adds value to the performance, then the task might be better assigned to a human performer. This approach is useful to an extent in that it takes into consideration will and intention as well as behaviour and cooperation. This dualism however also suggests a human-machine hierarchy, which has encouraged me to demonstrate how I am performing within the performance and to validate this hierarchy through a separation of agency between human and machine. I perceive this dualism to be in the mind of the audience too. In performances where this separation was not as clear, I received more questions from audience members related to agency and human control. The terms will and intention are problematic as they suggest a deterministic desired outcome which often relates to a more rigid view of virtuosity discussed earlier. In the context of my own work, I use the term intention to mean my intention to engage, interact or cooperate.

In some of my recent works, I have preferred to consider myself as a performer within the system, rather than a performer controlling a system, and thereby creating a flatter hierarchy of agency and rebalancing how I perceive my own influence. The system consists of hardware, software, and human components. I contribute to this system through different roles as a composer/performer/technologist similarly to how other components contribute to the system through their different roles. I see little benefit in separately defining these roles in a way that suggests an inherent hierarchy. I am the designer of the system, but to suggest that I have full control minimises the affordances of the technologies and other components used, as well as their own idiosyncrasies that also form part of the system. It also negates the agency of the designers/developers/creators of the components. In my practice, the tools I use include a laptop, Max, Ableton, a gametrak controller, custom-made controllers, IMUs (inertial measurement units) which provide motion data, and a WiFi router. These tools in isolation and in combination shape and inform my practice. While the affordances of the controllers are more obvious, the sensors and programming environments used also play a significant role in the design of the system. Snape and Born (2022, 221) discuss the aesthetic agency, materiality and human-music-technological assemblage of Max, presenting the argument that Max is not neutral because it has inscribed technical and aesthetic possibilities. In my own Max patching, I make use of generative and responsive procedures, which are easily afforded in Max. However, highly instructed sequences akin to a notated score can be cumbersome to achieve in Max. Therefore, the affordances of Max, and ease or difficulty of creative expression using Max, become a component of the performance system.

The gametrak controller (Figure 1) has been a popular experimental musical controller largely due to its flexibility and affordability (Freed et al. 2009). I have been drawn to it for a few reasons, including because it affords micro and macro scales of movement, which makes it flexible for designing sound and movement combinations that are

Figure 1. Gametrak controller. Photo by Daryl Feehely. Used with permission.

gesturally symbiotic. The data resolution of the controller is 12-bit or 16-bit (depending on the OS of the attached computer) which, although is of a relatively low resolution, still allows for small gestures to be programmed because small changes in physical movement can be detected. This resulting flexibility also means that it is not necessary to dictate to the body how it should move using the controller, but instead the system can be adapted to how different bodies move with the controller. I expand on this adaptability in a later section. Another reason I like to use the gametrak is because it is an object with which I can physically interact. The tactile nature of the controller offers some advantages over using IMUs in a performance setting. If I choose for it not to be a wearable, I have more autonomy over my interaction with it. Using a gametrak is also a more visual experience for an audience to perceive and make sense of, rather than using an IMU which may be hidden to the audience. It is also possible to combine these in a performance system, pairing the precision of the IMU and the tactility of the gametrak.

The performance system becomes not only an assemblage of components, but an assemblage of assemblages with intricacies that act upon other components. For example, the resolution of an analog pin on a microcontroller becomes an integral affordance within the performance system. The system is irreducible, in a similar way to that of a piano. In describing a piano as a system, I might list the components and their functions, and outline how they are interlinked. I may start by describing the keys, or how a performer acts upon the piano, or describe the resulting sound when acted upon. Describing a hierarchy adds little value to the description, but describing how the components interact provides a better representation of the piano as a system. To understand the relevance of the hammers I must consider their function in relation to the whole system. In my own performance systems, it is the interaction of the components where my interest lies, and where I feel I should give careful attention. To use another analogy, tuning a string on an acoustic instrument affects the overall tension, impacting the tuning of the other strings. When viewing the system as an assemblage of assemblages, it is easy to understand how making adjustments to one component of the system will have an impact on the others and the overall system output. Developing a familiarity with the system will allow for some prediction of the impact of adjustments to components, but mostly the impacts could not be predicted. It is more appropriate, and more interesting to me, to observe the impacts. This observation of behaviour allows me to position myself as a component within the system, rather than externally as the controller of it.

Hierarchy and Component Behaviour

In a flat hierarchy and decentred performance system, it is important to be a well performing part of the system, rather than to exert control. It is easy for an audience to visually perceive how a body is behaving and therefore *doing* in performance. It is less easy to perceive how the computer behaves or how the controllers behave. While I am the only component with intention within the system, I am not the only component doing or behaving, and as a result I do not overemphasise the importance of intention. Despite the importance of the roles of components within the system, the idea of measuring the amount of *doing* from each component feels inappropriate. Therefore, I see it as more useful to consider the components as cooperating, rather than controlling. A controller has certain affordances and these inform my behaviour as well as other aspects of the performance system. Changing a component changes the behaviour, the interaction and the system overall. For example, the gametrak controller provides data on seven parameters simultaneously (x, y, z position data of both hands and a footswitch). Therefore, when designing with this controller I am inclined to consider how the movement of one parameter affects another. There is harmony not only in the movement of the body and resulting sound, but a digital harmony and hybrid cooperation which reflects the relationship between multiple axes of movement and multiple components.

Assemblage and Actor Network Theory

All components within a performance system are incorporated so in order to create congruence. The performance incorporates technology, but it is not about technology. The performance incorporates the body but it is not about the body. It is about what this incorporation produces. The assemblage of components allows for the inscribing of practices into artefacts. The components acting within the system become entangled and a boundary between human and machine fails to fully convey the behaviour and affordances of each component, as well as the relationship. In describing the system from Latour's (1996) Actor-Network Theory perspective, we can consider how each component (actor) is understood further by examining its own components. These include code I have written, code others have written, tools designed by others, and affordances of sub-systems and objects. The outcome (be that a system or performance or a work) is the result of the combined agency of all sub-components as actors. The construction of the system is a non-linear process and is designed based on the various interactions and cooperation between components. For example, an audio process can be understood as an actor, and an understanding of its role and performance in the system must include its nodal connections, i.e. the material in which it is processing. Piekut's (2014) focus on actor-network theory as a methodology (largely based on Latour's work) provides a useful foundation for challenging human-machine dualism, considering all actors by their behaviour, on 'equal ontological footing' (195), rather than defining human and non-human actors.

The adoption of actor-network theory and as a methodology does not mitigate the issues of perceived human-machine dualism in performance. I often receive questions related to my performances asking what is technically happening, and how much I am responsible for the output verses how much the technology is responsible for the output. This suggests that for some audiences, human control relates to the quality of the performance, and virtuosity is determined by those boundaries between human and machine.

The Performing Body

The body has an obvious physical presence in a live performance. Emmerson's (2012) discussion on live or living electronic music suggests that the *living* is within the behaviour of the system. For my work, system agency might be better considered as system behaviour. The behaviour of all components or aspects of the system produces collective agency. This provides a perspective that negates the need for identifying control and intention. The body is not performed by the mind or the system but instead it is transformed and given space within the system to retain bodily autonomy. With this autonomy, I can choose and define the body's involvement and participation. The body in this sense is not to be observed in order to evaluate its appearance or performance, but to recognise the role of the body by its behaviour in the system.

I experience this embodied performance as a reclaiming of the body and the space in which it occupies. The seven parameters of the gametrak mentioned above are important in designing a system, but these individual parameters become less relevant in the performance. If I have designed the system well, the performer's conscious awareness of the data should disappear, and be replaced with their own conceptualisation of their movement and its relationship to the system as a whole. This sense-making, I hope, is perceivable by the audience and therefore allows the audience, the performer, and the performance to move beyond the technology. If the focus remains on the technology, it is likely not embodied for the performer, and could be perceived by an audience as a demonstration of the use of the technology—technology for technology's sake—rather than a performance. When there is some level of understanding about the technology and there is some communication through that, we can then engage with it in a more meaningful way. My understanding of audience reception influences the design of the system. As a performer I am drawn to physical controllers because of their tactility. I am also drawn to them because they offer something else visual to which the audience can connect.

I view the use of the body during performance in a similar way to technology; it is not a demonstration of the body. I want to communicate through the body in a meaningful way and not present or observe the body. Rodgers (2010) interviews highlight some of the conflict around the use of one's body in performance. Z and Kelley both discuss an expectation of women to use their bodies. Kelley highlights the exploitive nature of this, 'there's something emotionally blackmailing about an audience, like they're needy and demanding emotionally, and the performer has to emote and satisfy them' (238). Sonami similarly is concerned by performance as service. She is less interested in embodiment of a performative action, and more interested in the 'concentration, and the focus the performer radiates' (230). If the body is perceived as an instrument and evaluated with a traditional view of virtuosity, this might lead to an expectation of the exertion of control over the body and the potential for objectification. However, when expanding the definition of virtuosity to include system virtuosity as discussed above, the body in electronic music is not presented for observation, but wholly reclaimed, thus removing a sense of shared ownership and retaining autonomy within a shared space.

The body and technology can be considered in combination as they relate to audience reception. For example, a performance with an IMU attached to a performer's hand is technically very similar to a performer holding a smartphone. However, the performance and audience reception of each could be very different. The smartphone is technically a lot more transparent and an audience familiarity with the phone as an object takes some focus away from the body as an instrument and places more focus on the phone as an instrument (Figures 2 and 3).

Observations from Workshops

The body's interaction within the system transforms the body. My body moves and behaves differently while performing within these performance systems than it does otherwise. In their study on musical affordances with gestural controllers, Tanaka, Altavilla, and Spowage (2012) found that where there was prior knowledge of the controller, participants struggled to disconnect the controllers' activities and movements from which they were already associated, and participants found it easier to engage with controllers with which they had no prior knowledge. Controllers typically focus on small gestures, such as individual finger movement (e.g. table-top button-based MIDI

Figure 2. Hand with IMU. Photo by Daryl Feehely. Used with permission.

Figure 3. Hand with phone. Photo by Daryl Feehely. Used with permission.

controllers and gloves with flex sensors) and muscle movement (EMG muscle sensors). With the gametrak controller (Figure 1) and my custom-made string-based controllers (Figure 4), there is less risk of the interaction being shaped by an existing association since these usually involve a larger range of movement, or a combination of micro and macro gestures.

Despite this lack of familiarity, there still exists inherent suggestions within the controllers not only because of my own design decisions but also because of the contributions from the hardware component and software designers. During workshops

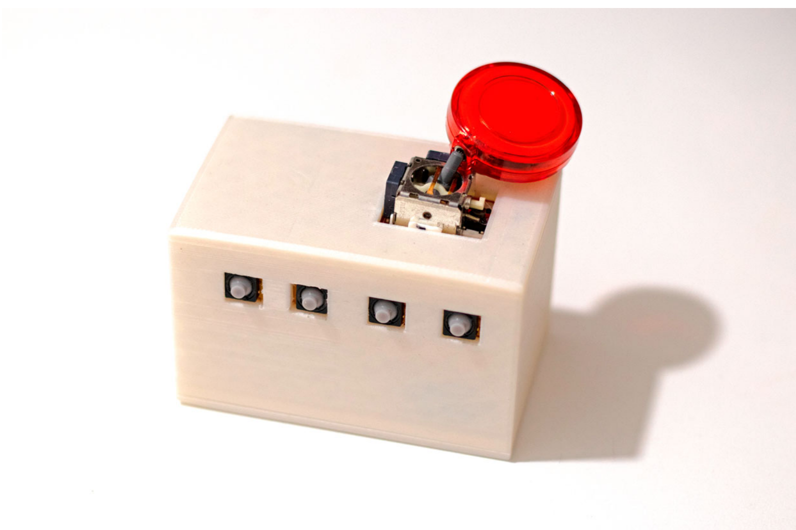

Figure 4. Joy (prototype of a custom-made string-based controller). Photo by Daryl Feehely. Used with permission.

where I introduce gestural sound making, I have observed that many workshop participants do not appear to move in a manner familiar to them. Instead, they appear to move in a new way to this new interaction. Although I have designed systems to have minimal dictated movement, many participants will want to know how to explicitly use the controls and, at least in the beginning, are engaged in a very cognitive way. Although there is freedom of expression and interpretation, these systems (and objects) have my own practices inscribed into them. The movement of my body, not just the dimensions of the controller, becomes embedded within the hardware-software system with which the participants are engaging. Suggestions of movements are still inherent. For example, a sound with a sudden attack could suggest a striking motion, a slow attack might suggest a more elongated gesture. In my experience working with others connecting physical gestures to sonic gestures, there may be some similarities related to amplitude envelope (as it relates to the production of acoustic sound), but as we continue the participants interpretation and engagement becomes more individual, going far beyond trying to represent the sonic qualities of the sound to expressing an individual meaning of the sound. Learning how others interpret and embody sounds in this way has helped me understand my own movement-sound relationship and helped me develop methods for incorporating individual body movement into the design of a system, rather than defining body movement as fixed within the system.

Similarly, the controllers themselves suggest ways of engaging. For example, the gametrak has two strings, participants typically hold one in each hand. I do not see a way to create neutral controllers and systems which have complete freedom for participants, so I instead focus on flexibility and adaptability within the system design. Even with my inscribed practices, the aim is that performers can more freely and intuitively engage with these instruments in a manner which is respectful of their body and autonomy. When I work with performers individually, we can discuss this physical relationship and find new ways of moving and interacting, and adapt the mapping of the data so that it is comfortable for the performer. Even where something must happen in a particular way in a piece, it is still possible to build in flexibility so that the effect can be realised in multiple ways using the controller.

As an example, in my work *Transition* (2016) for viola and electronics, there is a particular process that is triggered by moving the controller forward past a threshold. During the performance, the violist triggered this in two different ways—one was to move his right arm forward and return it, another was to keep his arms as they were (close to his body) and move his whole body forward by jumping. The data is the same but the two gestures differ significantly, thus producing different meaning in performance. This provides flexibility for the performer technically and expressively. Another performer may find different means of moving to achieve the same outcome. The focus is not on what they do, but that the system has flexibility and facilitates expression and bodily autonomy. What they do and how they choose to perform has a significant impact on the meaning of the performance. It is not important that the audience understand the mapping of this data, but that they will perceive the gesture and potentially construct their own meaning for this.

In another work, *Hear to Listen* (2020), for flute and electronics, the performer, using the gametrak, stretches upwards to trigger a freeze/sustain effect. This trigger is effectively a button push, but the gesture to trigger it is meaningfully connected to the effect it produces, so much so that it also suggests the material played. A note is sustained and triggered to freeze. The note can be unfrozen (buffer cleared) by bending down beyond a set threshold. The moving upwards can musically suggest the playing of a higher pitch to sustain. Performatively, it gives the impression that the note is being thrown upwards and suspended in the space. The pressing of a button could not achieve the same effect. The performer can trigger this skilfully in a way that connects the physical gesture with the audible gesture. This results in a meaningful haptic illusion for the performer and audience. It is an illusion with a very real impact on how we experience the performance. Changing the physical gesture, even if the sound did not change, would still change how the sound was perceived.

Parviainen (2012) discusses Merleau-Ponty's idea of reversibility, where seeing the action that produces a sound brings about the imagination of that sound, and hearing the sound causes the listener to imagine the action. This occurs with known action-sound couplings, which can guide our perception of artificial action-sound couplings (Jensenius 2007). Parviainen suggests that the kinaesthetic-visual-sonic expressions of dancers feed the imagination of the artists and the audience. The prominence, though, of kinaesthetic, visual or auditory modalities might be connected to modal preferences. For example, I find it very intuitive to connect my own movement to sound and to connect a physical gesture, or placement of the body, to a sonic output. In *Hear to Listen*, the performer found it more helpful to imagine physical 'rooms' that represented different sections of the piece and associated movements. Although there is no perceivable boundary between kinaesthetic, visual and auditory modalities (Robertson 2002, 303), performers can nonetheless assemble these as they embody the work. This multimodality is key to the performer's embodiment of the work, since the interaction of these modes guides their interpretation. Lotze (2013) outlines musical imagery as multimodal, consisting of motor, somatosensory and auditory elements. The performer's assemblage of modalities can feed back into the design process, whereby if something feels incongruent, the movement or sound can be adjusted to align with the performers imagery to better facilitate multimodal expression. This allows the composer and performer to design meaningful haptic illusions. As Peters (2013) has noted, haptic illusion can be a kind of cross-modal experience, which is not a misperception where senses are confused, but a cross-modal companion. I have found the term 'pseudo-direct causality' (Kirby 2019) to be useful in describing this multimodal connection. This occurs when you as the performer feel a strong connection to how a physical gesture causes a sonic gesture. However, this term is directional and only signifies how movement produces sound. It does not describe the relationship nor represent the feedback loop, which is central to the design process.

Making with the Body

Over time my practice has moved towards a movement-led design process. The movement-led process can start as a simple physical engagement with the controller. As I move with the controller, I consider what sounds should result from this movement. I consider the meaning of the movement. I try to review my level of comfort and interest in certain movements. This is a shift from a more cognitive approach to composing/making, towards an embodied process. During this process questions arise like why I want to move in a particular way, why I feel this movement should result in this kind of sound, or why my left arm moving across my body can indicate volume, when it feels clunky for my right arm. I am interested in observing these questions but deconstructing this intuitive process feels reductive. Where in the past I have focussed on connecting sound material to movement, now the material is suggested by movement, as a more mind–body-hardware-software integrated process. The performance emerges from this process. This movement-led design process requires all components to adapt and transform, producing system behaviour. The body also must adapt and transform, even though the intention in the design process is that this is done in a way that is respectful of the body, by allowing as much as possible this intuitive movement. For reproducibility, movements require rehearsal, where performers develop muscle memory for working with the controller, but this memory can be built on intuitive individual movement. This methodology attempts to look for ranges of comfort and means of expression, and asks how your body understands music, rather than exploring or pushing the body's limits. I consider this method of performing with the body as deeply embodied, and compassionately skilful. This methodology can be used to challenge binary definitions which create dualisms, such as body/mind, human/computer and human/posthuman. Grosz describes the body as:

> a discontinuous, non-totalisable series of processes, flows, energies, speeds and durations, [which] may be of great value to feminisms attempt to re-conceive bodies outside the binary oppositions imposed on the body by the mind/body, nature/culture, subject/object and interior/exterior oppositions. (Grosz, as quoted in Blackman 2021, 85)

This methodology embraces the posthuman, to assemble components, and embed myself in the process and resulting performance.

Data

Being able to create for individual bodies means dealing with the data that interprets the movement of the body. This data is often referred to as raw data (not yet manipulated/processed), however it is important to note that the data cannot be considered to be correct or accurate in any way as it is always a representation made available through different sensors and readings. My movement-led approach means that the flexibility is primarily with the data and the interpretation of the movement, rather than flexibility and accommodation by the performer to produce a desired data output. I can observe the shape of the data from the movement and consider what that affords. Data, controllers and sensors are not neutral. Controllers and sensors physically suggest movement. For example, if you hold a phone and I tell you that it is tracking your movement, you will likely move differently compared to when you use your phone for other purposes. Being observed/tracked will change how I move. The sensors themselves have their own idiosyncrasies, which the programmer decides how to handle. This is to say that while the physical movement you see is reflected in movement in the data, it is not without interference or external input. Translation and interpretation of data is always required. What follows is a practical discussion on data mapping.

Mapping

Direct mapping of data is where one piece of data is scaled and mapped to control a musical parameter, e.g. pitch. This is how most standard MIDI controllers function.

For example, a potentiometer/dial on a MIDI keyboard can be mapped linearly to a fader, where rotating the dial could affect volume or a filter sweep or whatever musical parameter is mapped to it. Moving beyond linear mapping and understanding gesture and movement requires analysing the movement of data over time. To see movement or gesture is to see time, something has changed from one state to another. To see movement in data requires capturing the data at a given sampling rate. Analysing the data over time can tell you something about the subjective characteristics of the movement, e.g. frantic, smooth, jumpy or static. In Figure 5, the visual representation of the up and down hand movement using the gametrak could be characterised as being smooth. We can then set the parameters for how the system identifies this smooth movement by identifying this rate of change over time.

The process is the same if I am programming this for my own body, or working with a performer. The figure shows the data over time for the movement that I have subjectively characterised as being smooth movement. With the help of this visualisation, I can set the parameters for smooth. For example, my subjective smooth movement experience could translate into data as follows, where my full range of movement is 0–1000 data points, I consecutively move between 20 and 40 data points measured at 100 ms intervals. I could therefore set a smooth threshold for within a range of 15–45. The system analysing this data can then identify the movement as smooth according to my subjective smooth movement parameters. This can easily be updated for another body, where their subjective smooth movement experience is measured as 12–28 for example. This means if the piece requires smooth movement, the performer does not have to change their representation of smooth, but the system can be adapted to it. This very simple calibration means that the system can easily be designed for individual bodies. This calibration requires access to the raw data coming from sensors/controllers. These raw values on their own do not have meaning, we give them meaning, which is culturally constructed, subjective and often highly individual. For example, when I hold a string of a gametrak controller and reach my hand upwards, it displays a value of 2972. This in many ways is an

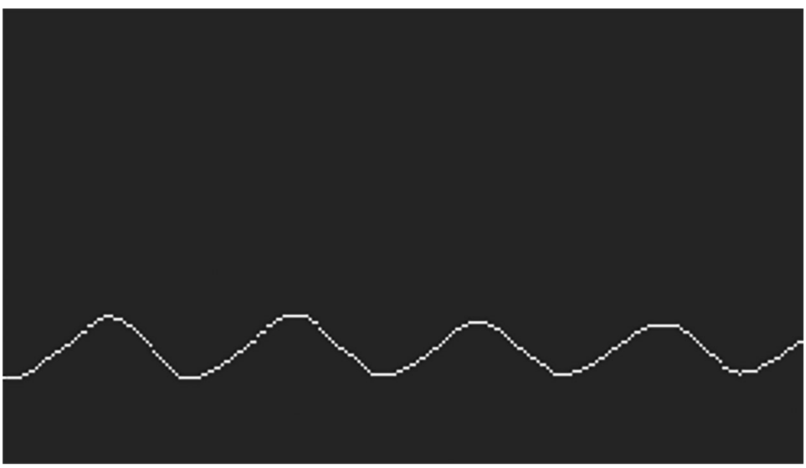

Figure 5. Visual representation of movement on the gametrak z-axis showing an up and down motion.

arbitrary value, it relates to the range that the potentiometer is capable of detecting, which relates to the voltage in which this component is operating. For my usage in software, it gives granularity, where the range of 0–4095 is more granular and can be more precise than 0–127. In this specific example, 2972 represents my maximum stretch height. Someone else holding the controller and stretching upwards might produce a value of 3190. Systems are usually designed to assume a range of possible values, in this case we might assume arm stretched upwards is detected between the values 2500–3600. However, prescribing a typical range is problematic and often non-inclusive. In this assumed case it would make it necessary for me to use the controller when standing for a gesture within this range to be detected. In software design, the plug-and-play and frictionless approach means more assumptions about the user's intentions are made. Systems could be designed to have some manual calibration, as well as a typical range (frictionless), allowing parameters to be open and transparent, and accessible for more users and more ways of interacting. If the user can see the raw data and the mapping, then they could perform manual calibration. Another advantage of manual calibration is that we can subvert the system. Perhaps I want the system to think my foot is my hand and see what kind of mapping this will afford. To open up parameters more is to open up interpretation and artistic control.

The advancement of accuracy of movement tracking has been hugely beneficial for artistic practice. However, a focus on developing accuracy in systems and sensors over expressive capabilities can be problematic because it assumes a position of neutrality that data can accurately represent the body and movement, rather than depicting a representation through interpretation. Accuracy over expression can also suggest that the body must learn to produce the data. Sensors and controllers as tools can allow for the reconfiguration of interaction and musical expression. They can facilitate new means of expression and hybrid cooperative performance systems. Hayes outlines how the use of such tools in her practice provide 'rapid and novel socio-musical reconfiguration' (2022, 31) which can be adapted to the participants to facilitate and not impose a method of working. Zbyszyński, Di Donato, and Tanaka (2019) discuss co-adaptive learning for both humans and systems. In their use cases, the training data for their interactive machine learning system is generated by human performers, thus avoiding a generic mapping of EMG data from a broad dataset. In their studies they did not indicate to the performer the movement that should or could be taken to perform the task. This resulted in co-adaptive learning, where the user adapted their movements through a feedback-loop to gain a better result, and the system learnt from that movement. This approach respects the affordances of the body and the system, and the result is a unique combined cooperative system.

Conclusion

Throughout these discussions, I have highlighted how boundaries between human and machine, mind and body, and software and hardware present limitations for the development of my own electronic music practice. Although the design process can focus on movement, then data, then sound, the perspective that the process is a translation of the body into data fails to acknowledge the non-neutrality of data and how the affordances of each component of the system informs and affects each other component. These dualisms also fail to account for how practices are inscribed into objects and systems. For example, the body is embedded in the software and the body also embeds the affordances of controllers. Working with controllers, sensors and data with the awareness of non-neutrality means we can more consciously inscribe our practices. We can design systems which respond and adapt to the body, as the body can adapt to the system. The body-centred, movement-led methodology can enable respectful and compassionate means for working with individual bodies. This methodology repositions the body as a component within the performance system which contributes to system virtuosity, where virtuosity results from the collaboration and agency of component parts of a system, rather than displaying virtuosity as an isolated component. This embodied and hybrid cooperative practice aims to reclaim the performing body and facilitate intuitive movement and expression in electronic music performance.

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