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The Cybernetic “Trap” Kit: Augmenting the Mechanical Assemblage through an Engagement with Motion Tracking Technologies

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The Cybernetic “Trap” Kit: Augmenting the Mechanical Assemblage through an Engagement with Motion Tracking Technologies

DISSERTATION

submitted in partial satisfaction of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in Music

by

Steven Michael Lewis

Dissertation Committee:

Professor Michael Dessen, Chair

Professor John Crawford

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DEDICATION

To

my parents, Katherine and Philip, for their endless love and support,
my friends, for being sources of encouragement, influence and inspiration,
and Kristen, for experiencing this latest journey with patience, grace and understanding.

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FIELD OF STUDY

Emergent Visual Processing Technologies Applied to Electroacoustic Music Practices

ABSTRACT OF THE DISSERTATION

The Cybernetic “Trap” Kit: Augmenting the Mechanical Assemblage through an Engagement with Motion Tracking Technologies

by

Steven Michael Lewis

Doctor of Philosophy in Music

University of California, Irvine, 2024

Professor Michael Dessen, Chair

The modern drum set is a result of the rich and varied material development of its material technologies, one which evolved from a stochastic collection of personal mechanized inventions into a standardized technological assemblage used around the world. Once referred to as the contraption (or trap) kit, the mechanical inventions yielded from new industrial developments of the early to mid-20th century led to a standardized outfitting of the instrument. As the standardization of the drum set proliferated, and the popularity of African-American-based improvisation practices in Hot Jazz, Swing and Bebop became a worldwide phenomenon, methods for playing this outfitted instrument developed, creating an inextricable relationship between an emergent performance vocabulary, the development of modern, mechanized musical technology, and the material and cultural conditions from which they both derived. Throughout the drum set's existence,

both the conceptual understanding of this instrument and the agreed-upon methodologies for its scholarly examination have undergone considerable transformations. This dissertation will argue that the drumset is not a site of cultural exchange because of the innovation in mechanical technologies alone. Rather, these innovation led to the development of an abstract interface that both supersedes and transcends the materiality of the drums. The drum set interface is a hyperobject consisting of individualized spatial assortments, ergonomic relationships, and gestural vocabularies that are particular to each player, yet exist independently of the instrument itself.

This dissertation will detail my experiments into virtual augmentation, which is a method of utilizing emergent digital technologies as the means to for processing a sound of a hybrid instrument in real-time. It will highlight not only my own performance practice that have developed but the collaborative work produced with some of the most in-demand jazz drummers in Southern California. Through the use of virtual technologies, this will dissertation will theorize on the musical potential of conceptualizing the drumset interface as a form of software. When conceptualized as software, the drum kit allows for the application of novel codes, new gestural relationships, and paths of motion that facilitate the blending, matching, and manipulation of sounds and performance techniques from around the world, making the instrument a domain of diverse cultural synthesis and profound musical potential.

INTRODUCTION

The Industrious Legacy of Ray Bauduc

Ray Bauduc is the unsung innovator of modern jazz drumming. Unknown to most drummers today, and written little about by contemporary drumming periodicals, Baudac's precision performance and swinging feel as a sideman for jazz singer Bob Crosby and his band, the *Bob-Cats,* inspired such luminaries as Mel Tormé, Buddy Rich, and Gene Krupa.[1] Tormé praised Bauduc, saying that "[he] wasn't a banger; he made music on his instrument. I've never forgotten how good he was in the Bob Crosby band. He got this funky, chunky, warm, and resonant sound from his snare drum. He was a very distinctive player"[2]. He was once described as "one of the brightest stars in the world of drumming" by the Ludwig Drum Company's founder, William F. Ludwig.[3] Along with the whistling Bobby Haggart on bass, Bauduc was the first drummer to ever record and perform the drum solo feature "Big Noise from Winnetka,"[4] which has since been performed by a diverse spectrum of artists,

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[1] Korall, Burt. 2002. Drummin' Men : The Heartbeat of Jazz ; the Bebop Years. New York ; Oxford: Oxford University Press.

[2] Korall, Burt. 1990. *Drummin' Men*. New York : Schirmer Books ; Toronto : Collier Macmillan Canada.

[3] Thomas, T. (1937). Dixieland Drumming by Ray Bauduc. WM.F. Ludwig Drum Company.

[4] Bob Haggart and Ray Bauduc. Big Noise From Winnetka. Big Noise From Winnetka, Decca Records, 1938.

such as Benny Goodman[5], Gene Krupa[6], Henry Mancini[7], Chico Hamilton[8], Cal Tjader,[9] even Bette Midler.[10]

Despite his accomplishments as a player, as Bauduc has never been given the enduring generational attention of his drumming predecessors from the New Orleans Jazz tradition, or his Bebop contemporaries. Even as he expanded the role of the drummer into a featured solo instrumentalist, others who followed his path within the Dixieland and Swing periods — Chick Webb, Gene Krupa, Buddy Rich, Mel Tormé, and Louie Bellson, among others — have been those whose prodigious talents and frontman showmanship are remembered as the drumming authority of their time.

A constellation of historical events, personal circumstances, and musical relationships that contributed to his contributions towards elevating the craft of modern jazz drumming being documented less than others. Even as Bob Crosby's *Bobcats* was the second most popular band of its time in 1937 (only behind The Benny Goodman's "Boys"), its frontman's vocal skills and persona self-admittedly paled in comparison to that of his brother, Bing. A consequence was that the group slowly waned in popularity in the very early forties, especially with the rise of historically enduring artists such as Benny Goodman, Artie Shaw, Tommy Dorsey (with whom Bauduc also played) and Glen

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[5] Jack Teagarden. Big Noise From Winnetka. Roulette, 1959.

[6] Gene Krupa. Big Noise From Winnetka. Gene Krupa at the London House, Verve Music Group, 1956.

[7] Henry Mancini. Big Noise From Winnetka.Days of Wine and Roses. RCA Records, 1959.

[8] Chico Hamilton. Big Noise From Winnetka. The Dealer. Impulse! Records, 1966.

[9] Cal Tjader. Big Noise From Winnetka. Mas Ritmo Caliente. Fantasy Records, 1958.

[10] Bette Midler. Big Noise From Winnetka. Thighs and Whispers. Atlantic Records, 1979.

Miller. Bauduc was also drafted into service for World War Two in 1942[11], occasioning his departure from the band right as its leader went to Hollywood.

Unlike "Papa'' Jo Jones with the Count Basie Orchestra, Zutty Singleton with Louis Armstrong's Hot House Five, Sonny Greer with the Duke Ellington Orchestra, or Max Roach's revelatory performances with Clifford Brown, Dizzy Gillespie, and the Charlie Parker Quarter, Bauduc was never in an seminal ensemble that defined a crucial period of jazz as it developed into a performance practice based around small-group improvisation and interaction. History is not without its ironies of course, as Bob Crosby's construction of the *Bobcats* was guided by the philosophy of a "band within a band," routinely featuring group interactivity between Bauduc, saxophonist Eddie Miller, and guitarist Nappy Lemare, while the rest of the 16-19 member ensemble supported the trio.[12] Moreover, Bauduc was from New Orleans and revered the stylistic and musical contributions made by the aforementioned Warren "Baby" Dodds, Zutty Singleton, and Paul Barbarin, and successfully integrated his "hot house" style of New Orleans Jazz drumming into the Dixieland Swing style.

No matter how multifarious the reasons are for Bauduc's musical contributions towards modern jazz drumming becoming less ubiquitous (or even known) over time, it is his material and industrial ingenuity in designing new mechanized "trap" kit technologies that has had a persistent impact on the contemporary drum set performance practice of his future compeers. It was his efforts as an industrious, resourceful technologist which have

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11 Thomas, T. (1937). Dixieland Drumming by Ray Bauduc. WM.F. Ludwig Drum Company.

12 Smith, H. (2021, January 31). *Bob Crosby's Bob Cats: Small Band Perfection.* The Syncopated Times. https://syncopatedtimes.com/bob-crosbys-bob-cats-small-band-perfection/

made these material innovations inextricable from contemporary drumset performance practices and the discourses that surround them.

Bauduc directly contributed to the design and construction of the Ludwig Speed King - the first commercially successful and mass-produced bass drum pedal for the "trap" kit.[13] While not the first mechanism of its kind, the Ludwig Speed King was the first piece of hardware to incorporate a spring mechanism that allowed the beater to automatically retract from the drum head, a post-mounted beater which reduced the required length of the beater shaft, and a solid footboard made of cast metal. These improvements made the mechanism sturdier and more durable than similar contraptions being invented in Germany and the United Kingdom during early 20th century.[14] These innovations collectively enabled drummers to effortlessly play at faster tempos for extended durations without experiencing fatigue - a necessity for Ragtime and Swing music, which often required drummers to use a feathering technique that softly outlined each beat on the bass drum. This playing technique would not have been possible without Bauduc's contribution to creating the prototype of the Ludwig Speed King.

Bauduc's second invention was perhaps even more consequential to modern jazz drumming's posterity, albeit in a less direct and obvious manner. He devised the design for a tympani-style foot pedal that could be attached to a tom-tom. When the pedal was pressed down, the tension on the drumhead tightened, causing a shift in the drums level pitch, and duration of resonance. Incorporating such a device into an existing set up which already included all sorts of contraptions and colorful percussion instruments meant that

13 Korall, Burt. 1990. *Drummin' Men*. New York : Schirmer Books ; Toronto : Collier Macmillan Canada.

14 Brennan, M. (2020). Kick it: A Social History of the Drum Kit. Oxford University Press.

Bauduc had to add another tom-tom to his percussion assemblage. Where once the trap kit consisted of one "small" tom attached to the bass drum and another suspended by legs on the floor next to the bass drum, Bauduc, placed another tom-tom (what is colloquially referred to as the "middle" tom) on top of or to the left of the bass drum, and to the right of the "small" or "high" tom. Bauduc referred to this tom-tom as his "pedal tom," which he routinely used during drum solos and small group interactions within the larger *Bobcat* ensemble.

Bauduc's innovation was twofold: the creation of a mechanized steel pedal contraption that could change the pitch of a drum in real time, which then necessitated the addition of another tom-tom to his percussion setup. The yield from his technological innovation was not only the novel invention itself, but an augmentation to his "trap" kit, one which created completely new possibilities for his own musical practice.

This augmentation ultimately had a resounding impact on the "trap" kit's technological interface. The pedal was a mere novelty - an interesting invention, although one which could not be easily replicated or manufactured by any of the leading drum manufacturers of the time (even though Dresden timpani came standard with mechanized, pedal-controlled tuning systems in 1870[15]). The extra tom did not need to be controlled by the pedal in order to be played; this new addition could simply be subsumed into the existing assemblage, affording the performer one more drum at their disposal, regardless of the incorporation of the mechanized pedal. Once this middle tom was included in the trap kit set up, a playing vocabulary was cultivated around the inclusion of this fixture, resulting in its permanence within the trap kit's technological assemblage. An unremembered

Perone, James E. "Percussion Instruments." *Music and Technology*: 191.

mechanical device, created by an equally bygone jazz drummer of the 1930's, were the harbingers for the standardization of the contemporary drumset interface known the world over today.

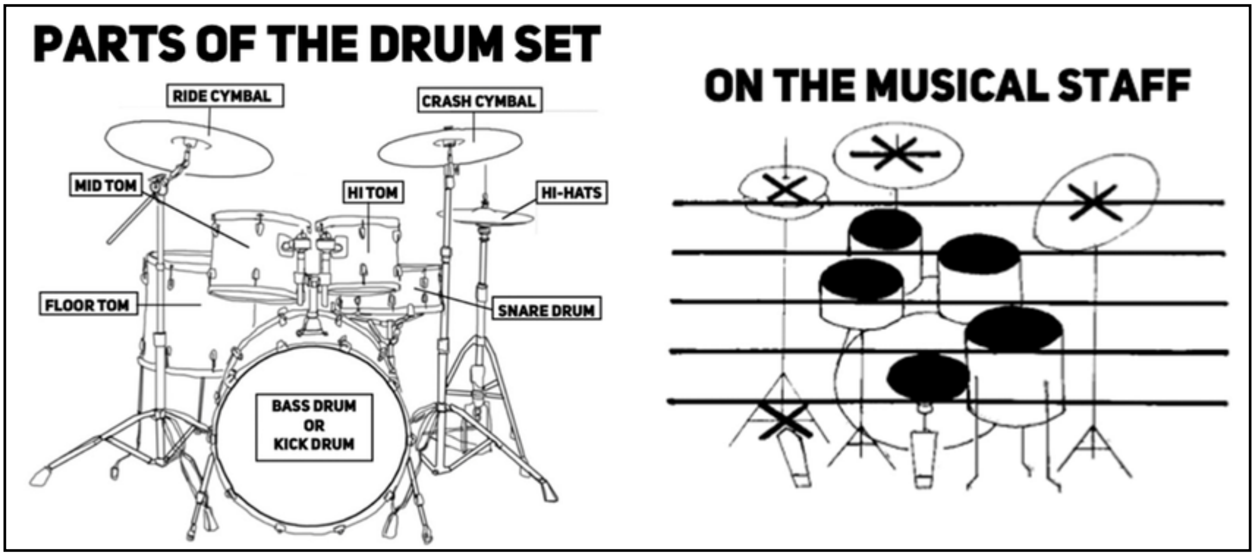

FIGURE I.1. THE STANDARDIZATION OF THE DRUMSET ASSEMBLAGE

When sitting behind the drum kit, this interface would be instantly recognizable to any drummer. Musical notation systems were even developed to account for the change to the assemblage. This universal set up and notation system suggests not only a specific arrangement of drums and cymbals that seems intuitive, but also a diverse range of performance techniques that enables the observer to recognize the instrument's ubiquity within a wide range of musical styles. Ray Bauduc's technological innovation transcended his own playing style, as well as the musical environment from which it was inspired, to affect virtually every single musical context where the contemporary drum set assumes a crucial role in music production. Henceforth, a drummer's personal style has been defined though an engagement with this technological assemblage, and certainly not in spite of the emergent mechanical technologies that led to this current standardization. It is the relationship between Bauduc's playing and his industriousness that resonates with this project, as the intention behind the software discussed in this dissertation, the Cybernetic "Trap" Kit, mirrors his inventive efforts that led to a new conception of what the standardized drum set would come to be.

The *Cybernetic Trap Kit* translates this tradition into a hybrid virtual space. It is a cybernetic extension of the drumset that aims to transmute the performer's interaction and musical relationship with the acoustic instrument through an engagement with motion tracking technologies. It prompts the user to embrace a screen-based, systems-oriented, iterative method of interaction and performance, and to explore the gestural and musical potentialities in a space where they function as mediators between the physical instrument and its virtual components. This application of technology is intended to exist as an extension of the rich and varied material development of the drumset, which evolved from a stochastic collection of one's own personal mechanized inventions into a standardized technological assemblage used around the world. Once colloquially referred to as the "contraption kit," the standardization of the drumset developed continuously over the course of decades, assimilating a broad range of innovations in response to the dynamic musical, social, and material conditions of the nineteenth and early twentieth centuries in the United States into one efficient instrument.[16]

Bauduc was certainly not alone in working towards this standardization, nor was standardization the result of individual ingenuity alone (nor could it). These mechanical inventions were realized through a combination of steadfast individual efforts and a rapidly

[16] Dean, M. *The drum: a history*. Scarecrow Press, 2011.

growing capitalist economy premised on industrialization and westward expansion. Improved infrastructure meant that better roads could be built that connected major port cities on the industrialized eastern seaboard to Chicago, enabling faster and more efficient transportation of raw and manufactured materials. Employment in factories increased over time, as less workers opted for living on the rural homestead and sought employment within cities. Relatedly, as more workers began to be employed in industrial environments, continuous and increased investment followed, leading to improved mechanical technologies in factories.[17]. This afforded the manufacture and distribution of interchangeable metals parts; no longer did the individual have to repair their own broken musket, razor blade, candle stick holder, or cymbal stand. - they just needed to be able to afford a spare part. No longer did the worker have to rely on their own skills to manufacture goods or provide services. This production was now done outside of the home, mostly in industrialized spaces - for a wage - where the time spent manufacturing products, and generating surplus value, was managed and made to be more efficient.[18]

The mechanical inventions yielded from these new industrial innovations and economic and social developments of the early 20th century were manifold, with some of the most significant being Walberg and Auge's Universal Cymbalum (what is currently referred to as the hi-hat stand), Ludwig and Ludwig's Speed King bass drum pedal, Leed's self-aligning drum lugs and collapsible snare stand, Slingerland's tunable, mounted and freestanding toms, as well as Avedis Zildjian's "K" Line of thinner, suspended drum kit cymbals, and of course, Bauduc's third tom-tom, driven from his now all-but-forgotten tom-

[17] McPherson, J. M. (2003). Battle Cry of Freedom: The Civil War Era. Oxford University Press.

[18] Brands, H. W. (2011). American Colossus: The Triumph of Capitalism, 1865-1900. Anchor.

tom pedal.[19] All of these contributions, in combination with a transformed industrial, post-Civil War, capitalist infrastructure, led to the definition of a drum outfitting; This standardization of the contraption kit directly correlated to the increasingly specialized labor required of the drummer in the swing and jazz ensembles of the 1920's, 30's, and 40's - the most popular music in the United States at the time.[20] As the standardization of the drum kit proliferated, and the popularity of jazz became a worldwide phenomenon, a method for playing this outfitted instrument developed, creating an inextricable relationship between an emergent drum kit vocabulary, the development of modern, mechanized musical technology, and the material, economic and cultural conditions from which they both derived.[21]

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[19] Brennan, M. (2020). Kick it: A Social History of the Drum Kit. Oxford University Press.

[20] Schuller, G. (1989). The Swing Era: The Development of Jazz, 1930-1945. History of Jazz.

[21] It is important to note that differences between individual and social levels of determination, especially as they relate to the establishing of the standardized drum set assemblage. The endeavors to build contraptions for one's own kit before standardization yielded innovative solutions for efficient percussion performance on an individual level. The new developments in the industrialized production of mechanized parts facilitated these individual accomplishments, but they were by no means the sole determinant in the solidifying the design and assemblage of the standardized modern drum set that proliferated around the world. This standardization *could* have come to fruition through any number of assemblages. And surely, anyone with the necessary skills and means could make virtually any assortment of modularized, mechanized percussion setup specific to their preferences. It is also important to acknowledge that all musicians are not currently and have never been engineers or designers, drummers included. The exchange of musical ideas and influences, observing live performances, and the spread of a new notion system that accounted for a standardized assemblage of percussion instruments, all played a role in the eventual standardization of the drum set on a social level. If one's main focus is to musically express themselves through an assemblage of mechanical technologies, then the technology may in fact not be a determinant at all, or nowhere near as much of one compared to social factors, which include playing with other musicians, observing other drummers perform, and listening to recordings that feature the standardized drum set. I view this as a form of artistic efficiency that is socially determined yet individually reinforced. It is also important to note that the standardized drum set is rarely left exactly intact: some drummers play "left-handed," some drummers add instruments to the assemblage, while others remove components. Yet, the core components to this assemblage — snare drum, bass drum, hi-hat and ride cymbal — are unanimously present in every particular arrangement. Moreover, the role of the drummer in an ensemble solidifies the kind of instruments included within the assemblage, which is another example of the universal elements included as part of the drumset being socially determined. As the development of the drum set continues to unfold, it is accurate to state that there its a cyclical phenomenon at work: technological innovation was (and is) the catalyst for individual attempts at altering the musical the technologies included on a personal instrument, yet these changes only became standardized on at the level of social determination, which was (and is) then further reinforced on an individual basis.

The *Cybernetic Trap Kit* aims to translate this dynamic, historical development of the 20th Century into the digital, cybernetic space. My vision throughout this process was to extend the history of developing a timeless instrument through the confluence of individual ingenuity and burgeoning industrial forces in the 19th and 20th centuries by applying that same dynamic within the 21st century's newest domain of economic and labor transformation: the digital space. The standardized drum set is perhaps the quintessential mechanized instrument birthed from industrial capitalism from 1870 - 1935, and this dissertation can be viewed as an initial attempt to discover a new version of this assemblage, one which reflects the changes in labor and production within an economy that is investing so much time and capital into virtualizing the way humans interact with each other - inside and outside of work.

Through the design and implementation of contemporary and emergent technologies — namely, interactive performance systems, sensors motion tracking and machine listening techniques — that I consider this technologically-mediated extension of the drums to be thought of as a virtual augmentation of the standardized, mechanical assemblage. From this virtual augmentation comes the opportunity for drummers and other jazz musicians to re-conceptualize the current aggregation of digital technologies as an assemblage of creative possibilities meant to expand upon the pre-existing musical instruments, forms, and vocabularies, as well as the social relations and specialized labor functions embedded in the jazz tradition. There are a number of fundamental characteristics of that comprise the practice and underlying concepts of virtual augmentation. It replaces a material component of a previous acoustic musical technology with a virtualization meant to emulate that same assemblage. In the case of the standardized drum set, this means taking a vital component of the drum set away - such as the floor tom - and having a virtual representation of the drum as a primary component of the new musical interface. Virtual augmentation modularizes the sounds that can be produced through interacting with these screen-based components. Otherwise stated, the sounds produced by whatever components have been virtualized are no longer bound by their previous material dimensions that comprised the acoustic version. The interface of the virtual components are designed in a way so that the user can combine both the material (acoustic) and digital aspects of the hybrid assemblage. Unlike practices that could be described as acoustic augmentation, the means through which a user processes any sound is mediated through a screen-based interface, rather than through the interaction of another physical object (magnets, microcontrollers, wearable sensors, et al).

Virtual augmentation is not meant to entirely replace the jazz drumming tradition or any musical practice previously or originally formulated in acoustic musical settings. Rather, a synthesis between the virtual and physical elements is meant to subsume the two under an entirely new creative environment, one which elicits the performer to negotiate a balance between retaining a liberatory musical practice within the historicity of a musical tradition while simultaneously extending their vocabulary through a new engagement with contemporaneous, digital technologies.

This dissertation will specifically detail the recent collaborative efforts between the software designer of the *Cybernetic Trap Kit* (myself) and some of the most prominent drummers in the Los Angeles jazz scene, to develop a gestural vocabulary and playing approach for interfacing with this screen-based, hybrid instrument. These performance case studies will examine how collaborative projects between digital designers, music technologists, and performing drummers foster promising environments for developing design methods that establish a greater sense of historical continuity between acoustic and virtual instruments while simultaneously offering the possibility for gestural experimentation and the creation of a new vocabulary to accompany this cybernetic extension of the drum kit.

Music production can now consist in an assemblage of performance traditions, technological innovations, and historical, political, or social contexts, the synthesis of which can make the process of modern musical production, as well as the development of performance practices, seem opaque.[22] Through detailing these collaborations and the process of developing the *Cybernetic Drum Kit*, I will argue that these relationships are vital for leveraging the benefits of digital signal processing, sensor-based instruments, and interactive human-computer environments into a mediation with technology, one which does not preclude the use of existing vocabularies or performance models, but augments them into exploring the outer musical limits and possibilities within a configured material and virtual assemblage.

A secondary motivation for this project is rooted in my longstanding interest in exploring what it means to develop and retain the purportedly liberating musical practices and expressivity historicized in Modern Jazz musicianship and extend them through an interactive and improvisatory engagement with technology. My approach to using technology in a creative capacity is primarily directed by my connection to jazz musicianship, and more specifically, my approach to improvisation on acoustic drums. Over the course of the last decade, my understanding of music technology has transformed from

[22] Born, G. (2005). On Musical Mediation: Ontology, Technology and Creativity. *Twentieth-Century Music*, *2*(1), 7-36.

merely acknowledging its role as a productive force within the process of recording and distribution, into recognizing its expressive potential in a real-time context.

A third motivation is to inquire as to why so few drummers are using emergent technologies in a way that reflects the aforementioned description of Virtual Augmentation. Changes in musical technology alter the spatial, tactile, and social relationships involved in the processes of musical production, and it is within this process that individual musical vocabularies are determined. The use or incorporation of electronics or computers into the drum kit assemblage should in fact change the manner in which the instrument is approached. There is the potential to augment gestural relationships that were conceived of and fortified through one's interaction with the acoustic instrument. Yet, in the case of the jazz drumming tradition (or perhaps many other forms of drumming as well), it is difficult to determine where this is taking place, or to what degree this experimentation is occurring. Jazz drumming luminary Roy Haynes once regarded that jazz is most similar to western classical music in ambience and the discipline required from its rigorous performance practices, and remarked how the use of technology should reflect their similarities. This opinion is juxtaposed with the various ways that classical percussionists have incorporated electronics and real-time audio processing into their performance practices. Classical percussionists (and percussionists that become composers) incorporate electronics into real-time performance far more than drum set players.[23] In fact, the first piece that featured software built for the *Cybernetic Trap Kit* was played by two classical percussionists at the University of Toronto. It is rare to find a through-composed piece for augmented drum set and electronics, while there seems to be innumerable examples of the

[23] Rocha, F., & Stewart, D. A. (2007, February). Collaborative projects for percussion and electronics. In *Proc. of the Roots and Rhizomes Conference, San Diego*.

opposite; scores have been written for solo percussion, duets, and large ensembles that have all utilized real-time electronics.[24]

Reasons for this disparity may seem unclear, as electronics and percussion share aesthetic and technical similarities. Both consider noise a valid sound material at their musical disposal, and configuring a drum set or signal processing system can be heavily customized by each individual practitioner.[25] If a drum set is merely a custom combination of percussion instruments, what explains the relative paucity of personalized augmented electronic drum sets being utilized in any number of performance situations? What explains the current dearth in compositions written for drum set and real-time electronic systems?

My current practices in virtual augmentation have been conducted within a practice-based approach and initially inspired through an engagement critical inquiry between jazz and technology. Music worlds defined around the creative space that Modern Jazz occupies are primarily characterized by a commitment to acoustic music making, preserving historicized performance roles, and adopting a relationship to technology aligned with preserving and proliferating the past through the physically or digitally recorded artifact. This sort of marginalized alignment, one where technology is mostly seen as a productive force, has cultivated a creative space of techno-cultural homogenization. Modern Jazz's relation to emergent, computational technologies resists exploring how these new possibilities could potentially alter their creative outcomes and transform the existing social relations within the contemporary ensemble. Paradoxically, this orientation

[24] Ibid.

[25] Ibid.

exists somewhat anachronistically with the music's path towards canonization in the middle of the 20th Century. A contemporary synthesis with emergent technologies, especially within a real-time improvisatory context, is still left relatively unexplored. Through these collaborations with Los-Angeles based drummers, I try to inquire as to why this resistance has manifested as a cultural practice for jazz drummers.

Motivations for Using Motion Tracking

Defining Terms

I have selected motion tracking technologies from Jean-Marc Pelletier's cv.jit library as the primary technology for this project for several pointed reasons. According to Cycling74's (the makers of Max/Msp~/Jitter) the cv.jit library is "an incredible package of tools geared toward computer vision techniques that are built upon the open source OpenCV library."[26]. From this library, I built analysis algorithms from the data that the motion tracking objects in cv.jit outputs, and use them to control virtual instruments, or process my own real-time performance. It is important to note that this use of motion tracking is not computer vision, which can be generally understood as a science of providing computers with logic that resembles the human capacity for memory, retrieval, reasoning, estimation, recognition, and coordination.[27] Motion tracking technology assists in monitoring the movement of objects in a defined space and sending this data somewhere

[26] Robert Ramirez, "Content You Need: cv.jit," Cycling74, May 30, 2021, https://cycling74.com/articles/content-you-need-cv-jit.

[27] Learned-Miller, Erik G. "Introduction to computer vision." *University of Massachusetts, Amherst* (2011).

else (for example, another software) for further processing or analysis. This technology can be instrumental in three-dimensional modeling, home automation, video gaming, virtual reality, or human-assistive technologies, amongst a wide range of applications.[28] These are two distinct technologies, and those currently being used in creative work produced by the *Cybernetic Trap Kit* fall under the latter. Furthermore, the science of computer vision can easily be conflated with Artificial Intelligence, a vast field related subfields relating to many technologies, such as machine learning, deep learning, natural language processing, and generative modeling, amongst others. Broadly speaking, if Artificial Intelligence is endowing a computer with the ability to simulate the manner which humans can identify patterns, derive solutions, and even reason, then computer vision is the science behind training a computer to recognize objects through a visual input. This may require the use of technologies such as Deep Learning and Convolutional Neural Networks, but it is a branch of science that is distinct from Artificial Intelligence in way not dissimilar to how motion tracking is distinct from computer vision. After all, the ability to see and the capacity to recognize represent two different levels of discernment to which human can perhaps become unaware.[29] These terms can admittedly become confusing, as all all three technologies could be used together to create a software that can track an object moving in space, detect some of its characteristics by breaking the image down into pixels, and iteratively predicting what the object is until the prediction is accurate. So, in an effort to contextualize the *Cybernetic Trap Kit* in relation to these terms as practically as possible,

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[28] Sharp, Toby, Cem Keskin, Duncan Robertson, Jonathan Taylor, Jamie Shotton, David Kim, Christoph Rhemann et al. "Accurate, robust, and flexible real-time hand tracking." In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*, pp. 3633-3642. 2015.

[29] [29] Learned-Miller, Erik G. "Introduction to computer vision." *University of Massachusetts, Amherst* (2011).

any activity occurring within the sub-matrices interacting with the screen-based interface will be tracked, no matter what or who enters the space. Whether the object be a drumstick, hand, or any other implement, it makes no difference to the software. Because there is no object recognition being used in the immediate creative output demonstrated in the dissertation concert, then the technology in the software being used in this iteration of the *Cybernetic Trap Kit* can be categorized as motion tracking. There are gestural recognition features being presently built into the *Cybernetic Trap Kit* that are intended to recognize real-time activity inside the screen-based interface by referencing a library of hand gestures. This will be discussed in more detail in the last chapter of the dissertation. As I am currently working towards a version of the *Cybernetic Trap Kit* that uses the computer vision and Artificial Intelligence, I felt it relevant to provide definitions for both. In the case of Artificial Intelligence, it is used in this dissertation to reference the use of technologies used in music-generation platforms (such as Boomy, AIVA, and Amper A.I.), the assistive audio technology featured in DAW plug-ins that help automate the mixing or mastering process involved in music production. While it is difficult to determine the exact use of Artificial Intelligence in privately-owned software, the characteristic shared between most of these products is the use of machine learning algorithms that analyze an input in some function-specific way, such as classifying a digital audio signal as a particular instrument and adjusting its channel strip settings, or determining the characteristics of a drum stroke quantified by Sunhouse Sensory Percussion. In the first and last chapters I also use of the term Artificial Intelligence in reference to these cases and its analytical capabilities within these musical applications.

Technological Motivations

One of the main features of camera-based sensor systems, computer vision or motion tracking technologies, is their transparent (and increasingly ubiquitous) presences in society. Whether it be at a routine traffic light, an airport security line, entering a financial institution or government building, or even using facial recognition software to access the content of one's cell phone, the humans in these contexts are not so much users and more as subjects in these exchanges of information. In most of these contexts (and perhaps all of them not including the picking up of a cell phone and aiming it at one's own face) there is no interaction taking place between the human and technology. The human is subjected to the technology - likely without consenting to doing so - their unique identities compressed to a reductive set of numbers, the purposes of which are never made fully transparent to the subject itself. There is a feeling of powerlessness and alienation one can feel in the face of such technologically-mediated subjugation, monitoring and analysis, and this is to say nothing of the issue of ownership over this footage of one's own image and likeness, which is legally ambiguous and subject to interpretations that are contingent on a whole other sets of arbitrary biases.[30] There is also the issue of embedding an emergent technology within an existent economy before society actually has come to a comprehensive or collective understanding of these tools' respective utility. Emergent technologies tend to become subsumed into existing economic systems rather than used to transform our social relations to each another. Before society has time to collectively understand the transformative possibilities of a particular technological emergence or its

[30] Adams, Andrew A., and James M. Ferryman. "The future of video analytics for surveillance and its ethical implications." *Security Journal* 28 (2015): 272-289.

potential social or political effect, inventions using these new technologies are packaged as products that solidify existing relations between workers and employers. As it relates to music and performance, there is a tendency for potentially transformative technologies, virtual or otherwise, to be used to reify existing musical practices or used in the service of making a process in music production more efficient.

New technologies can become the means through which past creative and social outcomes were achieved. The "innovation" is found within making a process more efficient, not so much in improving on outcomes which could already be achieved. I find this tendency confusing, to the point of vexation: the sum of society's surveillance capacity and deep engagement with the emergent technologies is experienced by the consumer as the means for…unlocking one's iPhone? As the purportedly more secure means of authenticating and accessing one's bank account on Chase's latest online banking application? As a way to facilitate paying for one's groceries at Amazon-owned Whole Foods with a palm print? For whom do these orientations to surveillance technology benefit? These issues will be discussed in greater detail in the third chapter, with focus given to how these social relations to emergent technologies greatly influenced my approach to performing with the *Cybernetic Trap Kit*.

I consider it the responsibility of scholars and creative-based researchers who work with these emergent tools to view their pedagogy as an act of resistance to these systemic tendencies. Empowering individuals to appropriate these technologies of potential marginalization and alienation into a component of their creative practice, is a meaningful act in service to this resistance. Designing creative environments that subvert the ways in which humans are subjected to surveillance technologies on an every day basis is key to this critical intervention, as is creating a context where performers will be hyper-aware that they are not only being observed by cameras and humans alike, but that their gestural interactions with a technology that otherwise functions as an inconspicuous presence in our daily lives, will have a direct effect on the sonic processing and sound generation. Using the camera and its supplemental screen-based interface as the primary means by which gestures are actively transformed into multimodal art is a way to confront this technology in a conscious manner, and is intended to empower musicians to appropriate these emergent technologies in ways that serves their own art. How the camera tracks the performer gestures and translates them to scalable mapping parameters could nearly go unnoticed, yet that could never be the case with the heavily processed sounds that resulting from engaging with these technologies. This conceptual framework, along with the rest of the automated features in the *Cybernetic Trap Kit* software, served as integral components in this dissertation's complementing concert.

Dissertation Structure

The first chapter is working towards a theory of drum set movement and performance as a programmable code and technology of cultural exchange. I invite the reader to forego their conceptions of the standardized drum set as merely a physical object, and frame the instrument as an interface that supersedes its own materiality. I then cover the design choices involved in building screen-based interfaces, the considerations of which result from this conceptualization of the instrument as a hyperobject of musical and cultural exchange. I also discuss the benefits of musicians using Artificial Intelligence and A.I.-assisted musical tools as a way to learn about their own physical tendencies during performance, and the concepts of affordances and constraints, which proved instrumental while designing the software and strategizing to present its features to the uninitiated user.

The second chapter is a review of others' work in this field. This work is split up between two kinds of practitioners: music technologists who experiment with new modes of musical interaction and subsequently conduct experiments with these emergent technological assemblages through the drums, and professional working drummers who subsumes emergent music technologies into an existing creative practice. The *Cybernetic Trap Kit* is then contextualized within both practices, identifying the niche within which this software and the performance practices that result from its use occupies.

The third chapter is dedicated to documenting the design phases of the *Cybernetic Trap Kit*, and subsequently detailing the experiences that prominent Los-Angeles-based drummers had while interacting with the software. I also share and reflect on own my experiences experimenting with developing my own musical relationship to the software, specifically as it relates to performances practices pertaining to real-time audio processing.

In my closing thoughts, I discuss this creative work in the broader context of increasing onset of automation, the future of new musical labor, and the existentialist discourses surrounding these subjects.

CHAPTER 1: The Drum Set Interface as Programmable Code

The Drum Set as Software

It would be shortsighted to consider Ray Bauduc's technological innovation merely one resulting in the addition of physical material. The drumset is not only a cultural artifact but a musical technology of historical importance and industrial demarcation. Its material dimensions are an amalgam of the vast amount of human ingenuity and labor relations necessary to produce the instrument in its current form during the mid-nineteenth through the early twentieth centuries. Without the crucial improvements to roads and trade routes, an unmatched industrial capacity to produce interchangeable and interlocking mechanisms and metal parts, combined with the country's citizenry migrating to cities to earn wages in factories, the means of initially realizing and reproducing the standardized instrument simply would not have existed.

Yet, a drumset as a technology transcends its literal material dimensions - varying metals, woods, plastic, and rubber - and includes a highly individualized spatial assortment, ergonomic relationship, and gestural vocabulary that is particular to each player. The interface is an abstraction that supersedes the materiality of the drums. One could even say that the interface and its virtual object-oriented ontology fits the definition of Timothy Morton's hyperobject[31] - an abstraction or entity that contains a presence that one need not touch in order to understand and recognize its vitality and importance within larger processes - in this case, musical interaction and performance, including solo or group improvisation. To Morton, a hyperobject must possess two primary qualities:[32]

1. They are viscous, and possess "staying power" with those who interact with them.
2. They are nonlocal, and transcend the normal properties of space and time with which humans locally experience.

The drumset interface certainly qualifies. It is composed of a number of discret shapes in varying dimensions, the positioning and modularity of which determines the musical possibilities in real time. One could certainly think of how to navigate the interface without the necessity of its material components, and can do so in a manner independent of genre, style, or geographical constraints. Roy Haynes - widely regarded as the "father of modern jazz drumming"[33] - has one more than one occasion remarked how he does not practice in the traditional sense and rather *thinks* about the drum set, often opting to mentally develop new gestural vocabulary for the interface away from the kit and then only

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31 Morton, T. (2013). Hyperobjects: Philosophy and Ecology after the End of the World. U of Minnesota Press

32 Ibid.

33 Stephenson, S. (2011, November 1). Jazzed About Roy Haynes. *Smithsonian Magazine*, *2003*(December). https://www.smithsonianmag.com/arts-culture/jazzed-about-roy-haynes-95383611/

apply his ideas in real-time on the bandstand[34] [35] . One does not need to physically touch the drums in order to play the instrument, as drummers typically use the drumsticks, brushes and other handheld implements to actually create any sort of sound behind the interface or to mentally practice with it in a similar manner as described by Roy Haynes.

It is important to note that the inferred sounds and uses of the interface are not limited. The drum kit itself is modular, but so are the sounds. If the drums were replaced with pots and pans or upside-down bowls, but arranged in the same manner, a drummer would approach the interface in the same way. One does not have to look any further than the busker who uses found materials to emulate the act of playing the drums as proof of this.

The abstract interface is not only a hyperobject, but a form of software, able to be coded based on the whims of each user. When conceptualized as software, the drum kit allows for the application of novel codes - new gestural relationships and methods of moving about from drum to drum, cymbal to cymbal, node to node. In fact, a drummer's personal style can be thought of as the unique way in which they navigate these discreet paths of motions, which is to say how they combine these paths to form a gestural vocabulary behind the interface.

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[34] Milkowski, B. (2007, April 1). The State of Jazz Drumming. *Modern Drummer*, *31*(4), 74-91. https://www.moderndrummer.com/wp-content/uploads/2017/07/md329cs.pdf

[35] Micallef, K. (2011, November 1). Roy Haynes: The Reign Continues. *Downbeat*, *2011*(November), 26-31. https://www.downbeat.com/digitaledition/2011/DB201111/_art/DB201111.pdf

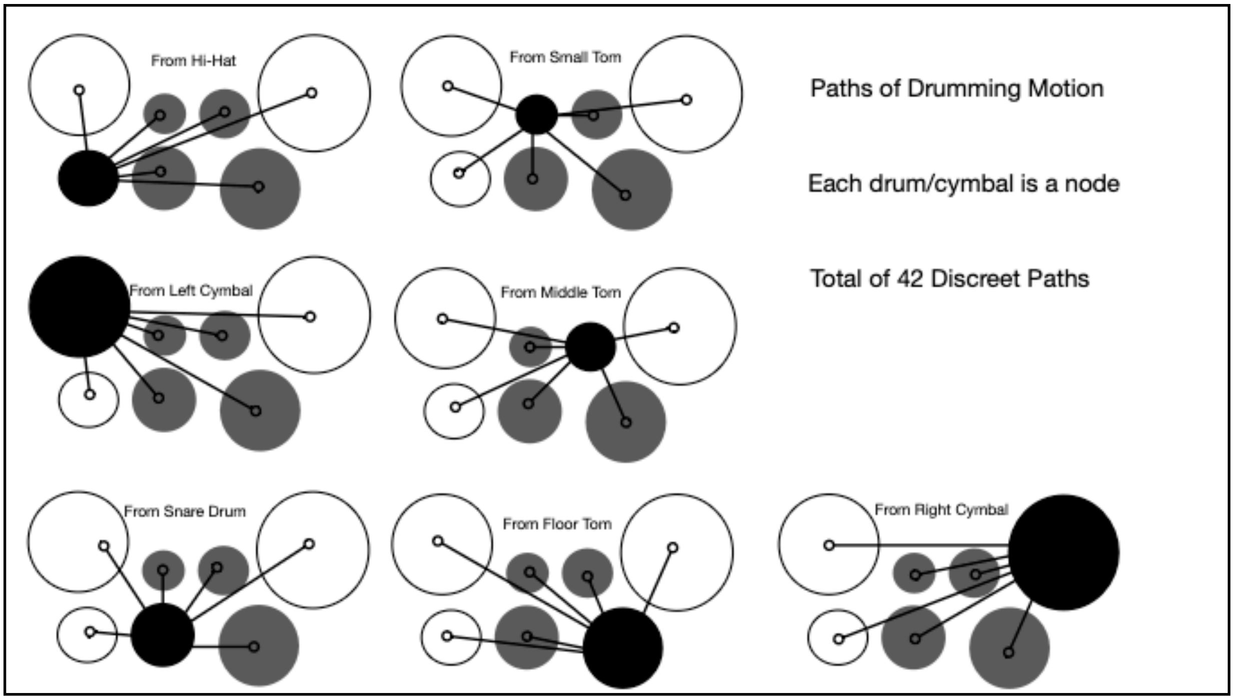

FIGURE 1.1. PATHS OF MOTION

These paths of drumming motion only demonstrate the linear directions each drummer can use with one hand, which pale in comparison to the amalgam of vertical combinations (playing instruments in unison) that can be achieved between the hands and feet. The majority of patterns played on the drumset consist of fusing linear and vertical motion together, which is afforded by the use of pedals and the malleable design of the drum kit interface.

Just as arranging pots and pans in a way that resembles the drumming interface enables the drummer to recognize the assemblage as a single object, the same can be done in the digital space as well. In fact, this cybernetic relationship to the drum kit is becoming increasingly more commonplace during an ascendant era of digital music production.[36]

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[36] D'Errico, M. (2022). Push: Software Design and the Cultural Politics of Music Production. Oxford University Press

Whether in the form of an electronic kit or as a representation on a computer screen, drummers can modularize and readily assign different sounds and instruments to each component of the interface without sacrificing their physical relationship. Therefore, it is not merely the drums themselves that facilitate this modular relationship to the interface, but the design and subsequent conceptualization of the drum kit as a single object supersedes the importance of any particular sonic or gestural association.

A drummer's unique vocabulary is not anchored to one particular drumset or its materiality, but is transferable to other standardized assemblages. These transferable, physical movements can be thought of as a variation of Mazzola and Cherin's notion of hyper-gestures in free-jazz settings;[37] each individual drummers' gestural vocabulary can "invent their own creative musical trajectories" while simultaneously influencing the ways in which other drummers express musical thought through the interface. If the interface can be conceptualized as a hyperobject, then one's personalized hyper-gestures are its complement. The standardization of the contraption kit into what is globally known and recognized as the drum set was a precondition for establishing this relationship between the interface hyperobject and its concomitant hyper-gestures. As a result of standardization, the instrument's interface transcends the drums itself, as does the vocabulary each drummer cultivates through their engagement with it. Without some form or degree of standardization, it would be difficult for one drummer to relate to or draw influence from how another mediated their vocabulary through the interface.

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[37] Mazzola, G., & Cherlin, P. B. (2008). Flow, gesture, and spaces in free jazz: Towards a theory of collaboration. Springer Science & Business Media.

The more deviation away from this standardization - especially in the maximalist direction - the less of this relation will occur, as demonstrated by drummer Terry Bozzio's drum set below.

FIGURE 1.2. TERRY BOZZIO'S DRUMSET

Whether or not Bozzio requires this gargantuan set up to expressive himself is not the primary issue here, as much is the recognition that an assemblage of this size reduces the performance, or the mediation of one's hyper-gestures through the hyperobject, as mere spectacle for the observing audience and other drummers. His set up is so many deviations removed from the standardized drum set that his vocabulary does not even consist of hyper-gestures, but as one that is localized to the sole confines of an entirely different, maximalist interface abstraction, one which many drummers would consider to be unapproachable and even foreign. It's the drumming equivalent of a driver removing themselves from a Toyota Camry to then drive another version of the same car with the operational interface of a Boeing 757: they might be able to figure out how to move it down the street, but that does not equate to that knowledge being particularly helpful or applicable to other people driving their own standard-issue Camry. In fairness to Bozzio, this setup is used mostly for solo drum performances and drum clinics. However, in the case of clinics and masterclasses, it is difficult to determine exactly what knowledge or musical gestures other drummers would be able to appropriate for their own musical ends. Bozzio's instrument is too far removed from the drum set's standardized outfitting to make his own embodied knowledge easily transferable or even understood.

Conversely, adopting a minimalist direction does not have the same localizing effect on the applicability of and relating to another's drummer's gestural vocabulary, as indicated by jazz drumming great Leon Parker's oft-used set up.

FIGURE 1.3 LEON PARKER'S DRUMSET

Parker routinely uses just three of the primary components of the standardized drum set, yet they are the three most fundamental: a snare drum - the focal point of the drum set interface - the bass drum, and the ride cymbal. Parker must work within these self-imposed constraints to find novel gestural vocabularies that are confined within the standardized interface. This is an approach that every drummer could take, making the vocabulary he derives within these constraints transferable and relatable. Furthermore, other drummers could extend this recognizable vocabulary and create their own variations using the other components included in the drum set's standard assemblage. In keeping with the Camry analogy, this is the equivalent of jumping out of one's 2013 model driving the 2023 model: yes, the materials have been upgraded, there may be a few enhanced features, but one's knowledge regarding how to drive the earlier model is completely transferable in operating the contemporary version; the primary components involved in moving this vehicle through time and space are still the same. This minimalist deviation would prove to be quite useful when designing the user experience of the *Cybernetic Trap Kit* during test-case studies.

The design of the drum kit interface facilitates the blending, matching, and manipulation of sounds and performance techniques, making it a musical instrument of profound potential. This potential emanates from drummers frequently adapting its abstract interface in unexpected, and at times, innovative ways. Imaginative drummers possess a deep understanding of the instrument's established practices afforded by this design, and subsume digital technologies into their existing practices to reify this tradition. And therein lies a problem, however imperceptible as it may initially seem.

Changes in musical technology alter the spatial, tactile, and social relationships involved in the processes of musical production, and it is within this process that individual musical vocabularies are determined. The use or incorporation of electronics into the drum kit assemblage should in fact change the manner in which the instrument is approached. There is the potential to disrupt gestural relationships that were conceived of and fortified through one's interaction with the purely physical, tangible, analog instrument. Yet, in the case of the jazz drumming tradition, it is difficult to determine where this is taking place, or to what degree this experimentation is occurring. A contemporary synthesis with the emergent technologies discussed in this dissertation, and their expanding possibilities within a real-time improvisatory context, is still left relatively unexplored.

A new gestural vocabulary for the drum kit can emerge through the crucible of this mediation between the analog and the digital. Furthermore, a creative-based inquiry into the benefits provided by Artificial Intelligence and A.I.-assisted musical technologies may provide deeper understanding of one's gestural relationship to the instrument. This could even yield a totally novel playing approach, one which is not subsumed under the weight of jazz drumming's own history, but rather subverts and reinvents it through a technologically- integrated design of the instrument's universal interface.

Benefits of A.I.-assisted Musical Tools and Instruments

In this particular application of Artificial Intelligence, gestures would have to be monitored, and used as the basis for the resulting musical synthesis that takes place. These analyses subsequently provide feedback to the performer, revealing a musical vocabulary mediated through physical gesture. The complex of influences, vocabularies, and social contexts that influence improvisation are, at their essence, reduced to quantifiable figures and signals which can be thought of as empirical representations of these physical gestures. The translation of these reductions into sonic outcomes transform the way in which human musicians subsequently respond to the correlations they make between their physical gestures and the existing cybernetic elements. This orientation to Artificial Intelligence does not only change the nature of musical production, but alters the way in which musicians approach their instrument in the cognitive and kinesthetic spaces that music creation exists.

A.I.-assisted music technologies afford the performing human musicians an added layer of analysis through which to consciously determine their subsequent choices. This is especially true in the context of indeterminate or fully improvised music, and nearly any real-time music creation involving Artificial Intelligence would have to fall within these performance categories. The musical choices each human performer makes during improvisation are influenced by individually-learned physical reflexes that are practiced, embodied, and memorized over time. It is rare to be met (or perhaps confronted) with a scientific analysis of one's playing in real-time, especially when performing with other human musicians in a shared space. Rather, social relations are being negotiated in real-time, with each musician discerning how to bring their learned reflexes into a space that is simultaneously dynamic and reliant on musical memory and personal experience. The emerging social context in combination with the temporal medium of improvised music, requires an incredible amount of craft and embodied knowledge to react in an instant, which makes the reliance on a vocabulary that is embedded deep inside each performer feel like an indivisible part of the process. This can be thought of as a form of physically-remembered knowledge, and it seems almost intuitive that entrainment to a musical form, style, instrumentation, or vocabulary would impede experimentation, radical innovation, or any type of significant deviation from the social factors that influence a given performer's musical choices.

Musical style also connotes certain timbres and instrumentation. Musicians position themselves within improvising ensembles in relation to the other instruments, and learn how to best communicate with them within that particular style. Knowledge of a musical style provides foundational knowledge to draw upon, but it does not necessitate a change in personal vocabulary. As a result, musicians can unconsciously bring a set of learned musical reflexes from one improvisational space into an entirely different context, regardless of its propriety. The use of Artificial Technologies in real-time improvisation transforms the creative space, which in turn, encourages inquiry and exploration, and requires a greater consciousness that is not present in a familiar musical situation where one can rely on musical reflexes. Since Artificial Intelligence technologies transform the social space of musical creation, using them requires a conscious, constant effort to remain in an improvisatory (or compositional) framework that requires focus on the granular consequences and macroscopic trajectories of physical gesture. If a musician fails to do this, then it is likely that their learned musical reflexes will be used at the expense of the transformed creative space.

Using the Sunhouse Sensory Percussion system (SSP) is a prime example of this phenomenon. The SSP system uses a combination of sensors and DAW-like software to transform the acoustic drums into either an electro-acoustic or a fully electronic drumset without the need to significantly alter the playing surface of the drumhead in any significant way.[38] The sensor technology creates a semi-virtual overlay on the acoustic drums, with each overlay consisting of up to ten distinct zones. These zones can be used to trigger a collection of sounds which are either included in the software or designed by the user themselves. Instead of wearing a controller, each drummer's unique physical approach

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[38] Esparza, T. (2016, November 10). *Say hello to sensory percussion 1.1.* Sunhouse. https://sunhou.se/blog/say-hello-to-sensory-percussion-1_1

to the instrument is used as a control signal for the further manipulation of these designed sounds. The velocity, speed, and location of each drum stroke can be analyzed and routed to control any available parameter for the purposes of processing each of the designed sounds that are programmed into the drum zones. These programmed sounds could be anything, but typically range from short, electronic percussion impulses, to sustained chords or drones. Since the sensors can only be placed on drums, many kits using SSP will map the impulses to emulate drum sounds, and use the tonal elements to generate the sustain that would usually be manufactured through the resonances of cymbals.

It is a commercial system marketed as an electronic extension of the acoustic drums, one which uses entrainment and gestural analysis to transform an acoustic instrument into one that affords the performer a completely different sound palette. And while it certainly does this, the measurement of one's physical gesture to such a granular detail, the wide variety of sonorities afforded to the drummer, and the amount of sounds that can be assigned to each region of the drum, makes playing an electronic instrument easier while simultaneously necessitating a change in the way a percussionist physically approaches the instrument. The affordances of Artificial Intelligence technologies facilitate both of these considerations at once. As a result, the transformation, triggering, synthesis and organization of electronic sounds are dependent on and responsive to the velocity, speed and location of one's gestures. This new technology has altered the creative space of acoustic drumming, requiring a novel gestural relationship to the acoustic instrument, as well as a heightened awareness of one's own physicality as it relates to musical intentions and outcomes. The creative space that SSP systems occupies is undefined by genre or a particular style, which is perhaps what experimental music should be thought of: the absence of something fully established rather than the presence of something new, like a technology. This experimental space has resulted in drummers from a myriad of cultural backgrounds, musical experiences, and technological skills to cultivate their own unique gestural relationship to SSP. The implementation of Artificial Intelligence technologies into the space of real-time drumming necessitates players learning an augmented vocabulary, and to cultivate a different, more sensitive relationship to their instrument, yet one which does not completely inhibit them from using the reflexes they have cultivated over decades.

The *Cybernetic Trap Kit* was built with this last consideration in mind. It encourages a potential user to think in terms of how computer programmers would conceptualize and procedurally apply a systems-oriented design method, which then emboldens their performance to explore the gestural possibilities and musical potentialities within a space that situates them as the mediator between the physical instrument and its cybernetic components. Through the design of computational systems, the implementation of multimodal data inputs into the system, and the leveraging of motion tracking technologies and techniques into a sensor-controlled visual interface, this approach to design can be thought of as a Virtual Augmentation of the drumset.

Design Principles

The physical, acoustic components anchor the screen-based interface to comprise a hybrid, virtual-acoustic instrument. The physical components of the drum kit are the snare drum and the bass drum - the main instruments in a purely acoustic assemblage, while the other parts of the drumset have been transferred into the digital space, translated by a screen-based interface that the drummer can interact with during performance.

The focus of developing the *Cybernetic Trap Kit* and the existing studies in the field of computational creativity intersect at designing screen-based interfaces for digital, musical expression, and translating these crucial considerations to the performer so that they may mediate with these emergent models for user interaction. It is impossible to distinguish the importance of the design of the interface (and overall system) from the expressive potential this hybrid instrument will represent to its user. Moreover, this project aims to contribute work that can be used by other artists to design systems based around a syncretic approach to multimodal computational creativity, with a particular focus on addressing the immediate issue pertaining to the *Cybernetic Trap Kit*: sonifying the visual domain through gestural interaction.

The *Cybernetic Trap Kit* acts as a digital overlay on top of the electroacoustic drums. The performance implications to such a design means that the drummer must generate gestural data to sonify a particular gesture played on the acoustic drums. Motion tracking techniques are instrumental in the design of a screen-based, two-dimensional interface that functions as a repository and reflection of evolving embodiments in relation to the hybridized instrument. The temporality of the music - the sonification of the gestures - is based on mass and the speed, direction, and proximity of its gestural movement to the source of data acquisition, rather than on a linear relationship to time. Creative programmer Denis Trček has previously stated that this approach predates the field of computational creativity, as it was Xenakis's strategy to using graphs and geometry that represented a divergent method to organizing time and generating sound.[39] However, it is through the field of computational creativity that artists can discover the relationships that

[39] Trček, D. (2021). Cruxes for visual domain sonification in digital arts. *Digital Creativity*, *32*(4), 293-306.

exist between light and sound. As it specifically relates to the *Cybernetic Trap Kit*, this is done through the sonification of movement tracking measured by motion tracking technologies and techniques, and translating these user-interactions into what computational artist Brigid Mary Costello refers to as a “synchronous rhythmic experience” for both the audience and performers. Costello distinguishes performing rhythms in the way a drummer would do, and creating a rhythmic experience, which is a practice she associates with dance, video games, and interaction installations.[40] There is a distinction between performing a rhythm on the drums and creating a multimodal environment where synchronous temporal control is felt within every dimension of the experience, such as the audio, visual, and body movements made while interacting with the system. Performing a rhythm on the drums is an individual act, yet a “rhythmic experience” differentiates itself at the granularity of implementation and context, as it is felt at the environmental level. Rhythm is an inherently multi-sensory phenomenon, which makes it a salient consideration in designing computational systems for user-interfaces and constructing user-interaction models that translate to a synchronous experience.

It is not so much that the intention of the design of the *Cybernetic Trap Kit* is to be the cause or site of some sort of transculturation, where integrating both the virtual and acoustic elements of the system necessitates an elimination of indispensable and creative possibilities provided through using technology, nor the historicized values, vocabulary, and playing approaches established by the innovators of an improvisatory musical lineage. Rather, a synthesis between the virtual and physical elements, is meant to subsume the two

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[40] Costello, Brigid Mary. "Moving in rhythms: what dancers and drummers can teach us about designing digital interactions." *Digital Creativity* 31, no. 3 (2020): 181-191.

under an entirely new creative environment, one which elicits the performer to negotiate a balance between retaining a liberatory musical practice within the historicity of a musical tradition while simultaneously extending their vocabulary through a new engagement with technology, one which aims to reveal the intricate relationship between its visual and sonic components. With that in consideration, the features and technological assemblage that make up this system fall under two of the fourteen software design patterns for Computational Creativity, initially collated by Glines, Griffith, ans Bodily: *Instant Feedback Design* and *Limiting Actions to Encourage Exploration*.[41] Both of these design patterns fall under the category of *User-Interaction Models*, and offer different but complementary features to the performer of the system. Certain motion tracking techniques, such as Blob Centroid, Bounds, and Direction Tracking, are mapped to specific sound processing parameters, provide immediate feedback to the performer. Frame differencing is used in a limited way to only enact certain virtual instruments, which allows for the performer to use a specific motion repeatedly to enact a similar sound every time, which can then be processed with any number of gestures measured through the aforementioned blob-tracking technologies.

The design patterns belonging to computational creativity provide a framework for constructing technological features of the system so that they can be revealed to the user in real-time. These considerations are essential in designing a CV-based interactive music system intended for transparency, versatility, and flexibility of use. Ultimately, it is the design of the interface that shapes the user experience. Effective, thoughtful design enables

[41] Glines, P., Griffith, I., & Bodily, P. M. (2021). Software Design Patterns of Computational Creativity: A Systematic Mapping Study. In *ICCC* (pp. 218-221).

the drummer to recognize the sonic modularity of the *Cybernetic Trap Kit* in an engaging manner that stimulates prolonged, continued experimentation into the gestural and musical possibilities at their disposal.

The following subsections will explore the design considerations encountered while programming performance systems for the virtually augmented drumset. Significant time will be spent detailing the issues involved in building an environment that simultaneously retains a drummer's ability to interface with the system in a physically familiar manner while also enticing them to expand on the vocabulary associated with the standardized drumset in an effort to explore other gestural and sonic possibilities at their disposal.

Designing for transparency

The drums are a physically demanding instrument, and while incredibly fine motor skills are not necessarily required to execute every musical gesture on the instrument, players must possess coordination between four limbs, and utilize these skills according to the temporal and dynamic fluctuations occurring in the music. Rarely planned in full, and often fully improvised, individual micro-phrases are played by each limb, ultimately contributing to what can be conceptualized as a macro-physical and musical gesture. Depending of the musical style and the performance model of the ensemble, the drum set player may be responsible for outlining the structural form of the overall piece while simultaneously executing the micro rhythmic phrases that comprise a macro-musical interaction with a soloist. With that in consideration, knowing a physical gesture "feels good" (or physically familiar) is an important factor in having the confidence to perceive that a musical gesture "sounds right" within the context of a broader creative trajectory being created in real-time. If the drum surface is altered, or if the player is required to be tethered to some device that they are otherwise unaccustomed to wearing, this may alter the way the player moves during a performance. Moreover, placing nearly anything on the surface of the drum will change its natural resonance, timbre, and the tactile sensation of playing the instrument. Depending on the placement of these materials, the drummer may have to alter their physical approach to the instrument in meaningful ways.[42] This could dissuade drummers from experimenting with electro-acoustic musical practices altogether, as previous research has revealed that "improvisors who perform simultaneously on acoustic instruments and electronic devices are likely to bring different means to their use of electronic gestures".[43]

A drummer may have to significantly adapt parts of their vocabulary in order to adjust to the specific ergonomics of what is, ostensibly, a different instrument than what it is that they are accustomed to playing.[44] As a result of changing the natural timbre and playing surface of the drum through physical augmentation, one's vocabulary would possibly have to be altered, thus negating years of effort in sculpting a physically-demanding performance technique.

Due to the ergonomics of the instrument, drum set players will typically construct their set up to minimize any excessive movement. This is because each drum stroke is a two

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[42] Tindale, A. R., Kapur, A., Tzanetakis, G., Driessen, P., & Schloss, A. (2005, May). A comparison of sensor strategies for capturing percussive gestures. In *Proceedings of the 2005 conference on New interfaces for musical expression* (pp. 200-203).

[43] Pras, A., Rodrigues, M. G., Grupp, V., & Wanderley, M. M. (2021). Connecting Free Improvisation Performance and Drumming Gestures Through Digital Wearables. *Frontiers in Psychology*, 1001.

[44] Dahl, S. (2011). Striking movements: A survey of motion analysis of percussionists. *Acoustical science and technology*, *32*(5), 168-173.

step process, respectively known as the preparation (and upstroke before making contact with the drum surface) and the rebound, which allows the drumstick to move back to its starting position by its own volition.[45] An ergonomically thoughtful drum set up is of paramount importance in consistently executing this two-step drum stroke, especially while controlling four limbs at once. Related to these ergonomic considerations, it is rare to observe a drum set player having to stand up nor walk in order to play every component of their configuration. By comparison, classical percussionists tend to have to move for functional purposes far more than drumset players during a performance. They often find themselves switching instruments and implements during a performance as well, with many of these required movements simultaneously executing both functional and musical decisions.[46]

There are performance motions required to stylistically execute the musical expectations of a particular composition or musical tradition. In many musical styles, drum set players are the sole percussive voice in the ensemble, and required to repeatedly play patterns over long periods of time. Playing in percussion ensembles is an entirely different experience all together, where each part is enmeshed within the greater percussive context. These contrasting experiences do not merely manifest in a spectrum of learned skill sets, and with them, a diversity of physical gestures required of (and expected by) each performer. Rather, these differences in experiences indicate one potential explanation for the paucity of electroacoustic and computer-mediated works for the drumset, relative to

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[45] Dahl, S. (2011). Striking movements: A survey of motion analysis of percussionists. *Acoustical science and technology*, *32*(5), 168-173.

[46] Rocha, F., & Stewart, D. A. (2007, February). Collaborative projects for percussion and electronics. In *Proc. of the Roots and Rhizomes Conference, San Diego*

the amount of experiment conducted by Classical percussionists within the domains of real-time, interactive music technology.[47] Presented with these issues, an indelible challenge in constructing an interactive system for the drum set is in designing it to be as transparent as possible during live performance. The system's design must function so as to not impede on the motions through which a drum set player executes a musical thought, nor on the sensory experience of playing the electro-acoustic instrument. In order to design an effective 2D screen-based musical interface, the programmer must apply their understanding of what perceptual psychologist J.J. Gibson refers to as his Theory of Affordances.

The *affordances* of the environment are what it *offers* the animal, what it *provides or furnishes*, either for good or ill. The verb to *afford* is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.[48]

The "complementarity of the environment" suggests that Gibson believed that affordances include properties of the environment and the actions that can be taken by the human within it. This definition of affordances was made in the context of how mammals perceive the physical environment around them. Designer Don Norman coined the phrase "Perceptual Affordances" to refer to the options unique to virtual, screen-based environments.[49] To Norman, there is distinction to be made between the affordances provided by physical components that comprise the computer (or any real-world tool or environment) — the keyboard, the trackpad, built-in camera, to name a few — compared

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[47] Rocha, F., & Stewart, D. A. (2007, February). Collaborative projects for percussion and electronics. In *Proc. of the Roots and Rhizomes Conference, San Diego*

[48] Gibson, J. J. (1977). The Theory of Affordances. *Hilldale, USA*, *1*(2), 67-82.

[49] Norman, D. A. (1999). Affordance, conventions, and design. *interactions*, *6*(3), 38-43.

to the options provided to the user through the design of computer software. This distinction informs his approach to human-computer interaction, which he refers to as "human centered, natural-based design."[50] This is an approach to designing environments where humans do not sense any type of resistance or struggle when interacting with a piece of virtual technology, and instead solely focus on achieving the desired end results of using any given tool. Often referred to as "natural design," Norman's design prioritizes the need to maximize the transparency involved in the interactions between humans and technology, to the point where humans ultimately forget that they are entering a technologically-mediated space at all.[51] Such design principles aim to enhance the transparency of use to the point where the experience feels unmediated through a particular technology at all.

Thor Magnusson states that conceptual simplicity, and common use functions are derived from an interaction model premised on transparency.[52] A well designed interface establishes the framework of an interaction model that enables the user to recognize the gestural options and utility afforded to them. This becomes especially important when the musical interface is a 2D video screen. The affordances programmed into virtual devices are more imperceptible than those designed into physical tools,[53] be it a saw, a steering wheel, a violin, or a snare drum. These virtual, screen-based interfaces also separate the musicians

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[50] Norman, D. (2013). The Design of Everyday Things: Revised and Expanded Edition. Basic books.

[51] D'Errico, M. (2022). Push: Software Design and the Cultural Politics of Music Production. Oxford University Press.

[52] Magnusson, T. (2006, October). Affordances and constraints in screen-based musical instruments. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles* (pp. 441-444).

[53] Magnusson, T. (2010). Designing constraints: Composing and performing with digital musical systems. *Computer Music Journal*, *34*(4), 62-73.

from the tactile familiarity musicians acquire through years of development. In the case of the *Cybernetic Trap Kit*, a clearly defined interaction model between subject (human) and object (virtual, screen-based software), is an absolute necessity.

Designing for versatility and flexibility

Ensuring that a piece of technology does not cause a complete disruption to naturally playing the instrument is a concern which exists at the forefront of designing the *Cybernetic Trap Kit*. As previously stated, this design decision can be categorized under the aforementioned principles found in Norman's Natural Design. However, completely adhering to the rules of Natural Design can parameterize the creative potentialities of a particular technology, especially when it is being appropriated as the means for musical interaction. After all, enabling Facial Recognition features to log into a phone is a completely different relationship to motion tracking technology compared to using it to gesturally manipulate incoming audio and visual signals in real-time.

In digital design, the counterpart to the affordances realized by the user are the constraints built into the system.[54] Constraints are established through parameter mapping, and the perceptual affordances of any system are realized through the user exploring the limits of its programmed constraints. Similarly, the physical and design constraints of any musical instrument (virtual or otherwise) define the way in which musicians can physically interact with its material dimensions. The expressive scope of this interactivity defines the constraints, which in turn, reveal the affordances in any system. This is to say that in any

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[54] Ibid.

digitally-designed musical system, creative activity is assessed by how the users navigate its constraints while leveraging the affordances provided to them. Whether these features fall under Gibson's idea of "environmental" affordances or Norman's "perceptual" definition is determined by the constraints, not in spite of them.

Robert Rowe defines an Interactive Music System as a system "whose behavior changes in response to a musical or physical input".[55] If a user does not change their behavior in response to the constraints and affordances in the system, then it is not truly interactive. Similar to human interaction within improvisatory musical environments, reciprocity must go both ways. Limiting the drummer through the principles of Natural Design alone would prevent the performer from realizing the full expressive, gestural, or musical potential that the system could afford them. This would limit the ways in which the system could react to user input, which would ultimately and severely parameterize the expressive scope of the instrument. Operating from such a stringent framework, the system designer would have to superimpose a layer of virtual technologies onto the drummer and the instrument in such a way that would negate the need for any interactivity during performance, thereby potentially eliminating the possibility of taking advantage of the efficiencies, constraints, and affordances provided by an interactive system. This makes little sense in an interactive context where the sole means of interfacing with the computer during a performance is a video camera.

The physical nature and ubiquity of their instrument requires drummers to execute a wide array of rhythmic patterns with stylistic accuracy and fluency, and to do so with particular coordination, dexterousness of touch, and musical sensitivity. Through the

[55] Rowe, R. (1992). Interactive music systems: machine listening and composing. MIT press.

multitudes of their responsibility, overlooked is the possibility that the functional motion to execute these patterns could alternatively be utilized to alter the sonic characteristics of the instrument in real-time.

Designing an interactive system that leverages buffer recording, machine listening and motion tracking technologies affords the performer access to musical material from a previous point in the performance. This temporally elastic, non-linear relation to their own performance affords the drummer to further process sounds by using expressive gestural motions that exist in contrast to the functional movement associated with playing an acoustic drumset vocabulary. Implementing this design consideration can expand the drummer's gestural motions from the instrument's acoustic timbre and material dimensions into a virtual space, permitting the performer to extricate themselves from learned rhythmic patterns, and to center their attention on deriving trajectories of motion intended for the explicit purposes of generating sustain on an instrument whose natural sonic profile mainly consists of short, densely layered and repeated impulses.

Simply stated, an approach to digital, screen-based instrument design based on transparency alone leads to a difficulty in perceiving affordances, while careless mapping leads to an inability to recognize constraints. From the user's perspective, ease of motion, flexibility, and clarity in design are of paramount importance as well. The inability to recognize constraints translates into a sloppily designed tool where its expressive scope is never fully realized. This makes style and creativity within a hybrid physical-virtual environment difficult to define, and challenging to evaluate.

Anthropocentric Design

When designing for flexibility, adaptability, and versatility, developers are operating under the notion that the human involved in any system of function should be the foremost concern of the user interaction model. This position reflects an underlying philosophy referred to as Anthropocentrism, which is the belief that humanity possess a cognitive supremacy above all other life and systems, and places the human at the focal point of whatever ethical issue or value they construct[56]. Not only are humans the focal point of such systems, but they possess a moral superiority to any other factors involved. Otherwise stated, humanity's own cognitive abilities justifies its actions within the world as ethical. This may seem readily apparent, as the human world is strictly designed by humans, but an anthropocentric worldview has recently come under question in an age where human consumption and usage of energy and resources has threatened the sustainability of ecosystems all across the world.[57]

J.J. Gibson's Theory of Affordances is fundamentally rooted in Anthropocentrism, since his idea of affordances is defined as a feature of the environment that can be appropriated or consumed by humans themselves. Don Norman's idea of Perceptual Affordances certainly falls under the underlying philosophy of Anthropocentric Design as well. In the case of J.J. Gibson's Theory of Affordances, humans have an evolutionary

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[56] Acosta, G. G., and C. R. Romeva. "From anthropocentric design to ecospheric design: Questioning design epicentre." In *DS 60: Proceedings of DESIGN 2010, the 11th International Design Conference, Dubrovnik, Croatia*, pp. 29-38. 2010.

[57] Ibid.

imperative to appropriate the natural world in a way that suits their needs in any environment. In Norman's idea of Human-Centered Interaction, a human's cognitive superiority over the natural worlds affords them the moral right to manipulate nature in such a way that it becomes more easily utilized, understood, and perceptual. The long term affects of transforming nature to fulfill human needs are less important than the tendency to view humans as existing apart from natural world.

While addressing the ways in which Anthropocentrism has led to potentially devastating climate change or environmental transformation is far outside the purview or scope of this dissertation, it is relevant to discuss how Artificial Intelligence could transform the understanding of contextualizing of Anthropocentric design practices moving forward. If humans build technologies from nature - which is to say that nature is subjugated to humanity's needs, justified through a perceived cognitive and moral superiority - then it is reasonable to project that humanity can become subordinates to the emergent technologies that it creates. Technologist Jerod Lanier has described Artificial Intelligence as the sum of human creative and intellectual activity. When Artificial Intelligence is used to create a work of art, the sum of whatever has been fed into in input layer of the algorithm is being "mashed up" together in order to output something that seems new.[58] The output is not so much simulacrum, but a form of automated, algorithmic pastiche.

In this emerging era for instrument design aided by generative Artificial Intelligence, one in which humans are relying on algorithms to synthesize the sum of accumulated, digitized human creative knowledge in order to automate tasks and make decisions on

[58] Lanier, J. (2023, April 20). There is No A.I. *The New Yorker*.

behalf of musicians (and in other circumstance away from music, for individuals, companies, and even governments), it needs to be stressed that neither the automated machine nor the algorithm is considered the moral and intellectual equivalent or superior of human cognition. If such a philosophy were to be systematized, the human would be resigning themselves to the output of an algorithm. Whatever the machine outputs should be accepted as truth, a since the data possess within it an ethical superiority to individuals . Because the input of the algorithm could be comprised of the total sum of creative, intellectual, or moral thought that humanity can generate, no contestation or questioning of the output would need to take place. This is the inverse position of humanity's anthropocentric views over the natural world: somehow humans could have authority over how they appropriate the environment but cede autonomy and moral authority over to technologies resulting from that very same appropriation.

In the case of the *Cybernetic Trap Kit*, the use of adoption of the term Anthropocentric Design is not a position of support for appropriating nature and potentially transforming the ecological world for the sole means of meeting the subjective and perhaps even subjective need and wants of a growing human population, so much as it is being alternatively employed to ensure that the human in centered as the arbiter and primary interlocutor of emergent technologies. The design of the software in the *Cybernetic Trap Kit*, and its resulting user experience, supports this initiative of centering the human in all mediations with motion tracking or computer vision.

CHAPTER 2: Literature Review

The following literature review spans a collection of experiments that intersect with the technologically-mediated practices and design concepts being explored through the *Cybernetic Trap Kit*. While none of these experiments completely intersect with the assemblage of technologies in the *Cybernetic Trap Kit,* each of them experimented with a vital technological component, design method, or focused on an aesthetics approach that influenced the current development of the project. This literature review covers two types of practitioners, both of whom relate to the focus of the *Cybernetic Trap Kit* is varying degrees: music technologists who experiment with new modes of musical interaction and subsequently conduct experiments with these emergent technological assemblages through the drums, and professional working drummers who subsume music technologies into an existing creative practice.

Current Practices in Drum Feature Extraction and Acoustic Augmentation

Spanning from the technologically elementary to the incredibly sophisticated, an abundance of methods have been recently developed to effectively capture physical gestures associated with drumming. Some of the most frequently implemented techniques for capturing percussive gestures include using piezo contact microphones, force sensing resistors, a microphone, accelerators, electromagnetic tracking, infrared, wearable sensors, or camera tracking.[59]

Gregorio *et al* connected a piezo contact microphone to a snare drum's surface in the *Augmented Drum System* to transduce vibrations on the skin into electrical signals.[60] The *Augmented Drum System* also uses electromagnetic actuation to create a feedback system between the actuated signal and drum strokes. Drum strokes are combined with the processed signal to create timbral variances based on feedback gain and time delay.

Gray *et al* designed *The Augmented Snare Drum,[61]* which used a webcam to monitor a player's brushwork from a close distance from the snare drum head, contact microphones, flex sensing resistors, and a PIC microcontroller to both sample the motion data and subsequently process the incoming audio signal. Through the cv.jit external package of tools in Max/Msp/Jitter, color and blob tracking were used to separate the brushes in both hands, and resulting measurements of which could be turned into individual histograms for further analysis, audio file triggers, synthesis or other musical mappings.

AM MODE uses machine listening to detect the incoming velocity of drum strokes and the resonating frequency of each to mix AM and FM Synthesis with the original audio signal.[62] Amplitude is measured by custom built software and objects in Max/Msp~ that

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[59] Tindale, A. R., Kapur, A., Tzanetakis, G., Driessen, P., & Schloss, A. (2005, May). A comparison of sensor strategies for capturing percussive gestures. In *Proceedings of the 2005 conference on New interfaces for musical expression* (pp. 200-203).

[60] Gregorio, J., English, P., & Kim, Y. E. (2017, August). Sound and interaction design of an augmented drum system. In Proceedings of the 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences (pp. 1-4).

[61] Gray, R., Lindsell, S., Minster, R., Symonds, I. M., & Ng, K. (2009). An augmented snare drum. In *ICMC*.

[62] Champion, C., & Zareei, M. (2018). AM MODE: Using AM and FM Synthesis for Acoustic Drum Augmentation.

not only perform the synthesis, but ensure that the envelope of the processed sound matches the duration of each acoustic drum signal. Dahl, Grossbach, & Altenmüller were able to track, recreate, and analyze 3D trajectories of hand and stick motion by attaching an LED light marker at the tip of each drumstick.[63] In an attempt to more accurately depict and digitally reconstruct the motions associated with music-making avatars, Bouënard, Gibet, and Wanderley digitally reproduced the temporal sequences of a drummer's playing motions by using a Vicon 460 system and a digital video camera.[64]

As varied as these methods are, nearly all of them attempt to capture the highly personalized and idiosyncratic nuances associated with drumming motions by closely tracking the variances in any combination of quantifiable attributes — timing, velocity, amplitude, and spectral centroid measurements — through modifying the drum's surface, body, or the drumstick.[65] Nearly all of the projects listed above utilize multiple techniques and technologies to exact enough data in real-time to accurately account for the numerous physical and musical dimensions of a drummer's performance. Maintaining a sustained level of transparency in acquiring data is another factor contributing towards the frequent implementation of mutli-modal measurement systems, as they tend to be less intrusive to the performer.[66]

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[63] Dahl, S., Grossbach, M., & Altenmüller, E. (2011). Effect of dynamic level in drumming: Measurement of striking velocity, force, and sound level. In *Proceedings of Forum Acusticum*(pp. 621-624). Danish Acoustical Society.

[64] Bouënard, A., Gibet, S., & Wanderley, M. M. (2008, June). Enhancing the visualization of percussion gestures by virtual character animation. In *NIME* (pp. 38-43).

[65] Tindale, A. R., Kapur, A., Tzanetakis, G., Driessen, P., & Schloss, A. (2005, May). A comparison of sensor strategies for capturing percussive gestures. In *Proceedings of the 2005 conference on New interfaces for musical expression* (pp. 200-203).

[66] Williams, P., & Overholt, D. (2021). Design and evaluation of a digitally active drum. *Personal and Ubiquitous Computing*, *25*, 783-795.

Other examples of this design consideration can be found in the *Pragmatic Drum Capture System*[67] and the *Digitally Active Drum* (*DAD*).[68] Aptly named, The *Pragmatic System* relies on a portable camera being angled to strictly capture only the drum strokes, drum surface and the neutral background of the wall. Simultaneously to this data acquisition, a dynamic microphone is used as a spot mic on the snare drum, quickly facilitating the designer to visualize drum gestures in two distinct mediums at once.

As designers Peter Williams and Daniel Overholt state, The *DAD* was constructed around the sentiment that the "natural resonances'' of the head should be respected, that the drums should be designed for an allowance of "different techniques, nuanced control, and co-location of sound and instrument…digital augmentation should not obstruct choice of technique".[69] Furthermore, the synthesis technique or degree of processing applied to the acoustic drum should not privilege any particular playing technique or musical style over another. The *DAD* assigned off-center locations on the snare drum to act as triggers for synthesis, where the audio amplitude tracking of each snare stroke is mapped to the amplitude envelope of the enacted subtractive synth sound. The snare drum head was separated into two primary regions: the Central and Accentric. While the Central Region preserved the acoustic sound from the middle of snare drum, notes inside the Accentric Region triggered the aforementioned synthesis processed, among other user-specified, time-based audio effects.

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67 Van Rooyen, R., & Tzanetakis, G. (2015, May). Pragmatic drum motion capture system. In *NIME* (pp. 339-342).

68 Williams, P., & Overholt, D. (2021). Design and evaluation of a digitally active drum. *Personal and Ubiquitous Computing*, *25*, 783-795.

69 Ibid.

Expanding on the methods of measuring audio and gestural data yields control signals that affect the acoustic drum signal in myriad ways. The creative implications of this prove to be increasingly consequential as the use of highly personalized augmented or actuated drum sets continues to proliferate, as multiple streams of control data can be routed to individual processing modules, all of which will affect the electro-acoustic output in an audibly distinct manner. These various models of data acquisition, control data routing and digital design are closely related to numerous projects dedicated to the concept of acoustic drum augmentation, including the aforementioned *An Augmented Snare Drum*[70] and *AM Mode,*[71] and the *Augmented Drum System*.[72] Projects of particular precedence and relevance to the *Cybernetic Trap Kit* are the *Digitally Active Drum*[73], the *Augmented Drum Kit*[74]**,** *Digitally Enhanced Drums.*[75]

Digitally Enhanced Drums uses a combination of many of the same machine listening and audio processing techniques while also incorporating time-based effects back into the audio signal, creating an output that is a mix of nonlinear and real-time events.[76] The original acoustic signal is recorded into a buffer, which is then routed to modularized processors. A probabilistic gating system was implemented that sent the acoustic signal to any number of sound processors while only outputting a filtered selection of the affected

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70 Gray, Lindsell, Minster, Symonds, & Ng, "An Augmented Snare Drum"

71 Champion & Zareei, "AM MODE"

72 Gregorio, English, & Kim, "An Augmented Drum System"

73 Williams, & Overholt, "Digitally Active Drum"

74 Michalakos, C. (2012). The augmented drum kit: an intuitive approach to live electronic percussion performance. In *ICMC 2012: International Computer Music Conference* (pp. 257-260). Michigan Publishing.

75 Amadio, M., & Novello, A. (2020). Digitally Enhanced Drums: An Approach to Rhythmic Improvisation.

76 Amadio & Novello, "Digitally Enhanced Drums"

signal at any given time. The overall musical aim of the *Digitally Enhanced Drums* was to provide multiple improvisational options to the drummer's disposal. The drummer could play alongside their processed signal, or attempt to play in contrast to this processed, gated, non-linear feedback.

Experiments with Virtual Drumming Environment using Motion Tracking

The *Virtual Drum Simulator* uses Computer Vision to build a "drum system that can be played using a webcam and a computer system alone," by defining sensor zones and identifying the oft-changing contours of a drummer's hands while simulating a playing motion.[77] The video feed acts as the interface for the user by highlighting every designed target with a colored frame, each one tethered to a distinct virtual drum or cymbal that would trigger if the user entered into its specified area. The OpenCV library in the Python programming language[78] was used to detect whether or not the contour of the hands inside the target rectangles was correct enough to trigger sound ("correct" being defined as whether the recognized position of the hands correspond to the motion of sticking that particular drum or cymbal in an acoustic setting). With such accuracy required to trigger each drum or cymbal, this software is intended to serve as a virtual replacement of an acoustic drumset, or an effective teaching or practicing tool.

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[77] Bering, S. R. F., & Famador, S. M. W. (2016, August). Virtual Drum Simulator Using Computer Vision. In *The 4th IIAE International Conference on Intelligent Systems and Image Processing* (Vol. 2016).

[78] Gollapudi, Sunila, and Sunila Gollapudi. "OpenCV with python." Learn Computer Vision Using OpenCV: With Deep Learning CNNs and RNNs (2019): 31-50.

Similar to the *Virtual Drum Simulator*, the *Air Drums* uses Computer Vision to simulate the sensation of playing an acoustic drumset.[79] Using the same OpenCV library as the *Virtual Drum Simulator,* the *Air Drums* use color tracking for Object Detection/Tracking, Event Detection, and its subsequent Drum Synthesis. Makeshift sticks wrapped in colored paper, along with placing a color sticker on the user's left thigh substitute for the hands and bass drum, respectively. By using Blob Detection, *Air Drums* can use the largest blob to run a *By Points Comparison* and an *Acceleration Comparison* on a frame-by-frame basis, thereby triggering note onsets through a prediction model based on present stick position in comparison to the previous data acquired from the last two video frames.[80]

In the tradition of incorporating a wearable sensor for the purposes (among many) of monitoring XYZ positional data, which is a concept similar to Max Matthews' *Radio Baton,*[81] The *Airstick Drum* integrates virtual percussion instruments alongside an acoustic drumset. Bluetooth sends data from the drummer's sticks to a computer which is then transferred into MIDI messages based on specific stick positioning.[82] MIDI messages for note onsets, velocity, and duration are determined through attaching gyroscope accelerators to the sticks. In *Air Drum* (not to be confused with the aforementioned *Air Drums*), a Microsoft Kinect is used in conjunction with the sensing framework OpenNI to

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[79] Tolentino, C. T., Uy, A., & Naval, P. (2019, August). Air Drums: Playing Drums Using Computer Vision. In *2019 International Symposium on Multimedia and Communication Technology (ISMAC)* (pp. 1-6). IEEE.

[80] Ibid.

[81] Boulanger, R. (1997, September). The 1997 Mathews radio-baton and improvisation modes. In *ICMC*.

[82] H. Kanke, Y. Takegawa, T. Terada, and M. Tsukamoto. Airstic Drum: a Drumstick for Integration of Real and Virtual Drums. In *Proc. The International Conference on Advance in Computer Entertainment Technology (ACE2012), pp. 57–69*, 2012.

track drumming movements within specific sensing zones.[83] Each sensing zone is mapped to a .wav file that triggers whenever the amount detected activity within these regions exceeds a certain threshold.

Current Practices in Multi-Modal Drum Design

Using the drums as an integral component in a multi-sensory, immersive experience is certainly not a novel idea, nor is the idea of using sensors to capture drumming gestures. Regarding the latter, this project distinguishes itself by the type of motion capture used and its subsequent artistic application.

Christos Michalakos's *Augmented Drum Kit* is a converted jazz drumset that uses a combination of commercial drum triggers, contact microphones, and an assortment of MIDI controllers to send signals into custom software designed in Cycling 74's Max/Msp~.[84] The modularized digital audio processors can be automated through the drummer's own performance, while the software also functions as a score control system. The score in this software design can be thought of as the data-driven determinant of which combination of processing modules are enacted at any given point (referred to as "cues") in time. Included with a predetermined temporal structure for the organizing of processing modules is a performance-driven mode, which enables the performer to control the score transitioning at their own pace. The transfer of control data can also be stopped completely, effectively freezing the current parameters' mapping values in place for any enacted processing

[83] Sarang, P., More, A., Gaikwad, A., & Varma, T. (2015). Air drum using Kinect and Arduino. *International Journal of Computer Science and Information Technologies*, *6*(2), 1153-1155.

[84] Michalakos, C. (2012). The augmented drum kit: an intuitive approach to live electronic percussion performance. In *ICMC 2012: International Computer Music Conference* (pp. 257-260). Michigan Publishing.

module. The technical development and design of the *Augmented Drum Kit* culminated in an electro-acoustic, intermedia performance titled *Torrrque*[85], where Michalakos used the electro-acoustic instrument to intervene on preset, timed events designed into the software in order for the performer to have a direct effect on the lights, speakers, and audio processing built into the system.

While it is motion tracking and not the drums that are the primary mechanism for the control or processing of audio signals in the *Cybernetic Trap Kit*, it adapts a number of the design choices made by Michalakos's *Augmented Drum Kit*. The *Cybernetic Trap Kit* is built into a larger assemblage of software design and technologies that includes the ability to route incoming audio signals to an array of processing modules. The *Cybernetic Trap Kit* has been organized into two distinct sections. Any controls dealing with video input or data acquisition are located at the top of the interface. Any user-input that organizes audio processing is located at the button half. In terms of composition and arrangements, the most substantial part of the software concerned with organizing sound and managing time are the automated score control and audio signal routing system. These features afford the user to create audio signal routings prior to the performance that would change based on an automated timer. Each section of the performance or piece can be thought of as individual signal routing. This timer feature manages the transition from one section to another without any user input during the performance. This automation is by no means compulsory, as the user does have the option to pause the timing of events, as well as skip to any of the pre-programmed sections (signal routings) during performance. Each audio processing module can be individually opened in the same manner in which each of the

[85] Michalakos, Christos. "Torrrque: Augmented Drum-Kit." In Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition, pp. 383-383. 2015.

video modules can be accessed. Broadly speaking, and similar to the software in the *Augmented Drum Kit*, the generation of sound is an improvisatory act, while the managing of time is an automated process, yet one that also affords the performer to intervene on the section-to-section transitions

Conceptually speaking, the artistic endeavors that are most aligned with the *Cybernetic Trap Kit* can be found in Christos Michalakos's *Icarus*[86], project. *Icarus i*s a hybrid interactive game/performance system designed for Michalakos's *Augmented Drumset*, an electro-acoustic drum set built from electronic drum triggers, embedded speakers, and contact microphones. In *Icarus,* the drummer has to navigate five distinct game environments, all of which are visualized through what Michalakos describes as "light art," which is an interactive light system that alters its color, tone and direction based on the data acquired through actively running the acoustic audio signal through machine listening techniques.[87] Audio signal processing and real-time performance tracking leverage the drum set into a controller for the video game, effectively improvising an electro-acoustic soundtrack that will differ in each iteration of the experience.

The sections of the hybrid game-performance environment are completely improvised, yet the rules within each of them are fixed. The order of these sections is also indeterminate, as are the player's decision once they enter each of the five levels. Rather than providing sequenced events that reveal a linear narrative or singular objective for each level the video game is designed to be an open world that encourages the performer to experiment and and freely explore each environment in order to discover their seemingly

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[86] Michalakos, C. (2020, July). Icarus: a game/performance for the augmented drum-kit. In *8th Conference on Computation, Communication, Aesthetics & X* (pp. 393-395). Universidade do Porto.

[87] Ibid.

emergent rules. The rules of these levels can be thought of as the particular gesture-to-sound (and by extension, visual) parameter mappings that must be realized by the performer so that they can exit one environment and enter another. According to Michalakos, each of the environments' visuals provide the audience insight into these gestural mappings while supplying the performers with a graphic score.[88]

Icarus is only one of numerous game-performance hybrids created by Michalakos. *Pathfinder* is a maze game where the drummer (playing the *Augmented Drumset*) has to adapt their activity, musical choices and gestures in order to make their way to the end of the game's path.[89] This effectively transforms the drum set into an expressive analog controller, applied to a virtual setting. The ending of *Pathfinder* is determinate, yet the musical manner (which is to say, the sonic outcomes) in which the player completes this journey can be highly improvised. *Death Ground* takes the game-performance dynamic to an extreme, where each of the active participants assume the role of avatars whose function it is to provide musical gestures that are thought to be "audio weapons."[90] Acquiring audio weapons is not just a method to eliminate the opponent, but the way in which the performer is able to organize sound. Every gameplay element in the environment is also directly mapped to a sound processing parameter, a type of synthesis known in the game development community as procedural audio. Procedural audio techniques create music and sound effects in real time based upon the indeterminate activity of a game element

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[88] Ibid.

[89] Michalakos, C. (2016, June). Pathfinder: A performance-game for the augmented drum-kit. In *International conference on Live Interfaces* (pp. 268-269). Experimental Music Technologies (EMuTe) Lab, University of Sussexand REFRAME.

[90] Michalakos, C., & Waerstad, B. I. (2019, May). Death Ground. In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-2).

within the virtual environment.[91] As opposed to using the static playback of audio files, player movement and decision-making determine the sonic outcomes of the parameter mapping.

SIIGNAL, one of Michalokos's most recent projects, uses hand-tracking in a VR environment to afford the user to physically manipulate a spherical object in space in order to generate, process and organize sounds.[92] It eschews the practice of using screen-based sequencers and instead relies on sonic gestures to procedurally control the timing of events, and affords the performer to use what Michalokos refers to as physics-based motion synthesis to trigger a collection of sample based audio files and to subsequently process these sounds with granular, additive, and subtractive synthesis techniques. Similar to the *CVDT, SIIGNAL* facilitates the player to explore the gestural possibilities in each section of the piece and provides them with the means to decide exactly when they would like to proceed on to the next signal routing.

The similarities between Michalakos's work and the *Cybernetic Trap Kit* are primarily rooted in how the drums are positioned within their respective multimodal technologies, and in conceptualizing the instrument as transducer for these interactive experiences. There are also parallels between structuring the different levels of *Icarus* as distinct musical modes that the performer can autonomously navigate through and the different performance modes included in the *Cybernetic Trap Kit*. Of all the conceptual congruencies between *Icarus* and the *Cybernetic Trap Kit,* the most meaningful of them is the structural freedom the performer experiences when interacting with each system.

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[91] Farnell, Andy. "Procedural audio theory and practice." (2014).

[92] Michalakos, Christos. "SIIIGNAL: an electroacoustic composition/instrument in Virtual Reality." In *10th Conference on Computation, Communication, Aesthetics & X*, pp. 386-390. i2ADS, 2022.

While there are game play consequences to musical decisions that occur in *Icarus* (as well as *Pathfinder* and *Death Ground,* for that matter), there is no set time limit on game playtime, nor a maximum allotted time to exist in any inactive states or formal sections in the musical composition. While there are no gameplay consequences to the *Cybernetic Trap Kit*, there exists a temporal elasticity that fuses the hybrid performance-installation into a dynamic experience that is at once emergent and indeterminate upon each engagement with the system.

A Brief Review of Commercially Available Products Combining Digital Technology and the Drumset

The experiments discussed in the prior sections were the results of academic endeavors. The drumming electronics that had the most impact on drummers' relationship to electronics are commercially developed, the most consequential being made available in the 1980's - 2000's. Three of the most prominent manufacturers of electronic drumset technology were Simmons, Alesis, and Roland.

Founded by music technologist Dave Simmons, Simmons Drums played a pivot role in how drummers developed an understanding of electronic drumset performance in the 1980's. The electronic set featured hexagonally-shaped drums which were essentially the interface for a two-channel synthesizer that functioned as the operating system for the entire kit.[93] According to Simmons, the drums were trigger pads for the synthesizer, which had to be programmed in by the user in order to generate the desired outcomes from a limited range of sounds. The combination of their digital sound palette and their visual

[93] "The Simmons Story," Simmons Drums, accessed May 5, 2024, https://simmonsdrums.net/history/

novelty made the Simmons SDS5 model increasingly widespread in the Pop music in 80's, used by likes of Prince, Depeche Mode, among others.[94]

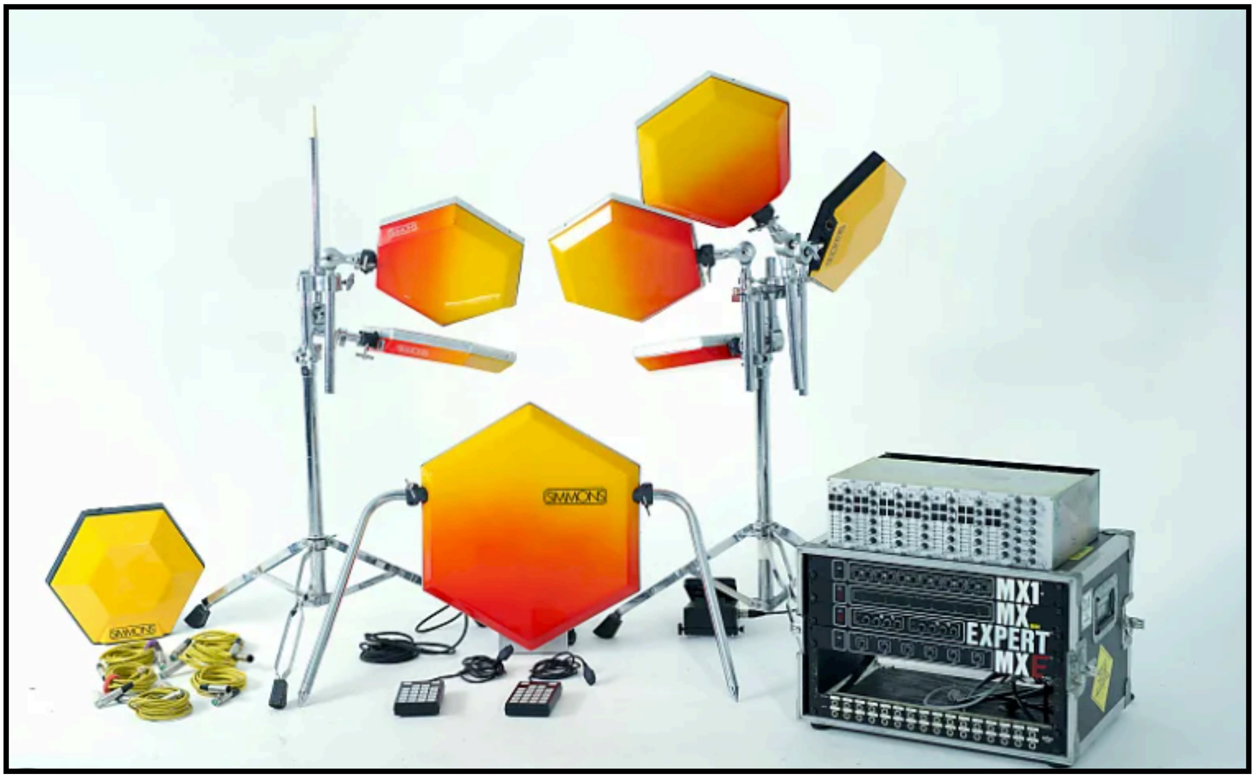

FIGURE 2.1. SIMMONS SDS5 ELECTRONIC DRUMSET

In the 1990's, Alesis built the DM5, an electronic drum modules intended to be a rack mounted drum pad that could turn the acoustic drum set into a hybrid electro-acoustic instrument. The DM5 would eventually be expanded to be an entirely electronic drum kit, and birthed other series of electronic drums - the DM8 and DM10 series kits - that featured modules that could be programmed with presets or user-loaded sounds. The most recent of their drum modules is the Strike Drum, which features a screen-based interface for each available drum set, and methods for making, saving, and uploading custom drum presets.

[94] Simmons Drums, "The Simmons Story."

Perhaps the most well-known and commercially successful of all modern electronic drum sets is Roland's *V-Drums* series - a company which has been involved in developing electronic drumming technology since the mid-1980's. Named after the distinct shape of the first commercially available models, the Roland *V-Drums* were designed to not only be a professional instrument, but were intended to offer a relatively silent practice solution at home.[95]

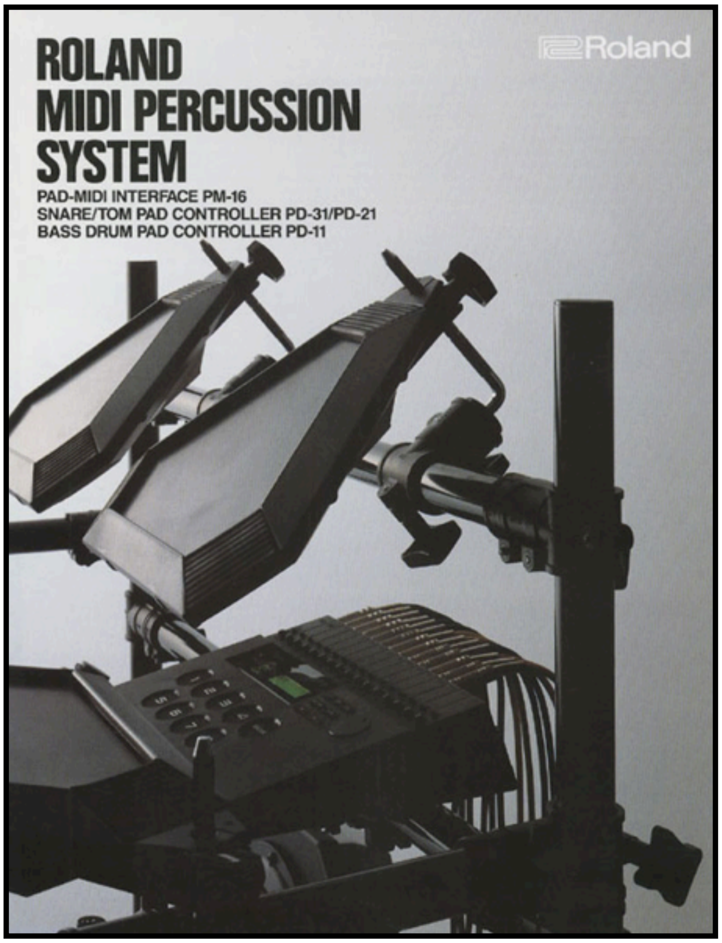

FIGURE 2.2. FIRST ITERATION OF THE ROLAND V-DRUMS

[95] Adam Douglas, "Redefining Rhythm: A History of Roland Drums," Roland, Accessed May 6, 2024. https://articles.roland.com/redefining-rhythm-a-history-of-roland-drums/.

Later iterations of the *V-Drums* discarded the novel shape of the drums and opted to use a mesh heads instead of plastic surfaces, which better emulated the sensation of playing an acoustic drumset. Roland 's primary goal was not only to offer the drummer a wide range range of percussive and pitched sounds to choose from but to do so while keeping the ergonomics relationship and physical sensation of playing the acoustic drums as intact as possible. Concomitant with the development of the *V-Drums*, Roland also made other electronic percussion that was not explicitly designed to look like the drum set, but could be played in its place or as a part of a hybrid instrument. These products include the PAD-8, *Handsonic*, *SPD-S*, and the *SPD-30*, commonly referred to as the *Octapad*.[96] The instrument is essentially a MIDI controller that featured eight evenly sized rubber pads that are intended to be used by drummers to control other external instruments, such a drum machine, a synthesizer, or a sampler.[97] The *Octapad* can be played by itself or combined with other electronic percussion from Roland to make customized assemblages.

FIGURE 2.3. ROLAND SPD-30, THE "OCTAPAD"

[96] Ibid.

[97] Ibid.

Since their introduction in the early 1980's the electronic drum devices - and many others like them - have occupied a polarizing space in the drumming community. A drummer may have to significantly adapt parts of their vocabulary in order to adjust to the specific ergonomics of what is, ostensibly, a different instrument than what it is that they are accustomed to playing .[98] As a result of changing the natural timbre and playing surface of the drum through physical augmentation, one's vocabulary would possibly have to be altered, partially negating years of effort in sculpting a physically-demanding performance technique. The polarizing discourse surrounding electronic drums as a substitute for acoustic drums support such negative feedback, and reflect the sentiments of those who actively (and at times, extremely) dislike the physical sensation of playing electronic or electro-acoustic set ups. Even though articles in prominent magazines such as *Modern Drummer*[99], *Drum! Magazine*[100] have gone to great lengths to highlight the efficiencies and features that electronic drums provide, internet discourse among drummers reveal how strong the aversion to changing the tactile sensation of playing the acoustic drums can become for many players. The language is often unapologetically strong in this regard, and frequently refers to the technological complexity of electronic instruments as an unequivocal detriment to their playing. Other negative claims center around drummers

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[98] Dahl, S. (2011). Striking movements: A survey of motion analysis of percussionists. *Acoustical science and technology*, *32*(5), 168-173.

[99] Roy Burns, "Drumming and Electronics" Modern Drummer. October 3, 2018, https://www.moderndrummer.com/article/december-1985-drumming-and-electronic-drums/

[100] Norman Weinberg, "Electronic VS. Acoustic Drums: Will A Clear Winner Emerge?," Drum! Magazine, Summer 2018, https://drummagazine.com/electronic-vs-acoustic-drums-will-a-clear-winner-emerge/

feeling a lack of physical resistance when playing on mesh heads, and consequently losing their touch and vocabulary on the instrument.

Other digital technologies have been used to completely virtualize the drumset, turning the instrument into tool for efficient beat-making for the modern music producer. Software plug-ins such as *Toontrack's EZ Drummer 3*, *Steven Slate Virtual Drums, GetGood Drums Library, Logic Pro X's Drummer* feature, *and XLN Audio Addictive Drum 2,* create a virtual representation of the drumset as its interface, but while the user experience is something more akin to an elaborate, virtualized drum machine rather than the feeling of actively playing the drums. These experiences remove the physically necessity involved in playing the drums in order to produce a litany of performance of varying quality. In these spaces of beat-making and music production, these technologies negate the polarizing discourses surrounding electronic and acoustic drums, since playing the instrument is entirely removed from there process of recording.

Drummers Who Subsume Emergent Technologies into an Existing Creative Practice

Marcus Gilmore is a drummer and composer based out of New York City. An improviser with an international presence, he is widely regarded as one of the pre-eminent, versatile, and creative drummers of his generation. He has played with some of the most renowned jazz improvisers in the world, including Vijay Iyer, Steve Coleman, the late Chick Corea, David Virelles, Joshua Redman, and Chris Potter, among a host of many other musical luminaries. Since 2016, Gilmore has been exploring the sonic potentialities of incorporating emergent music technologies into his playing set up, most notably, with Sunhouse Sensory Percussion (SSP).

The SSP system uses a combination of sensors and DAW-like software to transform the acoustic drums into either an electro-acoustic or a fully electronic drumset without the need to alter the playing surface of the drumhead in any significant way, or in a manner where a drummer would need to change their playing or gestural approach to the drumset. The sensor technology creates a semi-virtual overlay on the acoustic drums, with each overlay consisting of up to ten distinct zones. These zones can be used to trigger a collection of sounds which are either included in the software or designed by the user themselves. Instead of wearing a controller, each drummer's unique physical approach to the instrument is used as a control signal for the further manipulation of these designed sounds. The velocity, speed, and location of each drum stroke can be analyzed and routed to control any available parameter for the purposes of processing each of the designed sounds that are programmed into the drum zones. These programmed sounds could be anything, but typically range from short, electronic percussion impulses, to sustained chords or drones. Since the sensors can only be placed on drums, many kits using SSP will map the impulses to emulate drum sounds, and use the tonal elements to generate the sustain that would usually be manufactured through the resonances of cymbals.

Gilmore takes an alternative approach than the one described above. Rather than substituting these sustained sounds for his cymbals, he subsumes the sensory percussion into his existing set up, which consists of numerous drums, cymbals, bells, and other metallic percussion instruments. Gilmore has stated that the inherent sensitivity of the SSP system is simultaneously the greatest feature and the biggest challenge of playing with the technology (citation needed). When asked if he could recreate his performances with his electro-acoustic hybrid setup, Gilmore has commented the following:

It depends on how you program it…you really have to make sure that you…train everything exactly. Like I said, they're so sensitive, so, for instance, if I played a different kit tomorrow with the same exact sizes, and I have the same settings in there (the Sunhouse Sensory Percussion)...you can't just go on and expect it to be the same…the tuning will be different, so the vibration is different…what makes it amazing is that it's so sensitive but what makes it so challenging is that it's so sensitive.[101]

This incredibly high level of sensitivity is not an intended outcomes of the SSP system, but is the primary contributing factor in its success, as its ability to captures the granularity of a drummers gestural motions guarantees that the tactile relationship between the acoustic instrument and performance is retained while performing with the hybrid or electronic set up. Such a high level has not dissuaded Gilmore from his pursuit of experimenting with technology, as he has also commented on the software's versatility of use and the multiple functions it can serve within technological assemblage:

You can be a DJ if you want, you know, on your drum set. That's actually revolutionary. So you no longer have to rely on certain things that maybe we had to rely on as drummers in the past, you know, like having all these pads around, clicks tracks, or sometimes…even a band![102]

The sentiments expressed in this previous statement are reflected in his approach to working with the SSP system. Gilmore creates ambient pads, drones, and short synth sequences that are used in combination with an acoustic drum kit. He positions one drum with a mesh head and sensor to the rightmost part of his set up, and includes another two sensors on his snare drum and bass drum, both of which have plastic drum heads. The sensors on the mesh head will be used to cue tonal elements while the sensors on the snare and bass drums are used to augment their natural acoustic sounds with audio effects or short, electronic impulses. Effectively, he is able to control the melodic and structural

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101 Schafer, J. (Host). (2019, September 9). Drummer Marcus Gilmore Creates Continuous Melodies [Audio/Video podcast episode]. In *New Sounds*. New York Public Radio. https://www.newsounds.org/story/drummer-marcus-gilmore-creates-continuous-melodies/

102 Sunhouse. (2016, November 17). Sensory Percussion: Completely and Utterly Unprecedented [Video]. https://www.youtube.com/watch?v=z3OhUZvFTms

elements of each piece on the mesh head while freely improvising on the other elements of his set up.

There are numerous performances that document this approach within both group and solo settings. In some cases, Gilmore uses the SSP system to act, in his own words, as the "DJ" of the group, and in others, as a replacement for a band entirely. On the live performances of his compositions *Silouwave* and *Flash Forward*, Gilmore uses this hybrid set up to establish the sonic world of each piece before subduing its electronic elements in an effort to make space for the vocals of rapper Larry Mike Drew.[103] An audience member or listener can observe the changes in function that the SSP system affords Gilmore when the piece transitions from a solo endeavor into him accompanying a vocalist. Regardless of the level of percussive density he plays with at any given moment, the SSP allows him to establish and retain this sonic world in the passages that are more ambient and spacious.

Gilmore has also used the SSP system as a way to play compositions that once required the services of an entire band. He has routinely played a version of David Verielles's *Nube.*[104] The SSP system is used to cue ambient pads while Gilmore solos over these sustained sounds, similarly to how a drummer will solo over vamps played by other musicians. If the triggering of new pads can be thought of as the progression of the piece's score, then its formal elements are not so much automated as they are enacted, fully controlled by the performance decision of the percussionist in real-time.

[103] Schafer, J. (Host). (2019, September 9). Drummer Marcus Gilmore Creates Continuous Melodies [Audio/Video podcast episode]. In *New Sounds*. New York Public Radio. https://www.newsounds.org/story/drummer-marcus-gilmore-creates-continuous-melodies/

[104] Ibid.

Both approaches have been described by Gilmore as an evolution of what constitutes "drumset independence", a performance technique that features each of the four limbs doing something distinct but in an interlocking, synchronous manner. Within the context of the SSP system, Gilmore is now provided with the tools necessary to transform the drums into a harmonic and melodic instrument while retaining the natural timbre of the acoustic drums and resonant sustain of the cymbals.

The SSP system can be used in combination with the *Cybernetic Trap Kit*, which has been previously done in a way that reflects the approach Gilmore takes in Verielles's *Nube.* In my own practice, the SSP system has been used to enact sustained sounds while the CVDT is used to process the source material through motion tracking. This approach deviates from Gilmore's in the sense that I too use the SSP system to expand upon the sonic palette naturally afforded to me by the acoustic drums, but I then utilize motion detection and tracking technologies that are independent from the drum stroke itself to further process these sounds. I do not subsume the SSP within an existing practice as much as I use it in combination with the *Cybernetic Trap Kit* to create a layered technological assemblage through which drumset performance is mediated.

Other drummers have experimented with SSP in ways that are reminiscent of Gilmore's comments regarding how the software affords to the drummer to potentially turn their instrument into a DJ controller. Greg Fox - former musical director of Pioneer Works in Brooklyn, New York - was one of the first users of SSP, dating back to his release of self-described "post-free jazz" musical style captured on (he has never extemporized a working definition e on the meaning of this phrase, at least not in writing) *The Gradual*

Progression.[105] Released in 2017, *The Gradual Progression* explores, in Fox's own words, "responsive environments tethered to various aspects of the performance," by using SSP to sense "the emotionality and physicality of the world with the senses and through mental processes — about touching the walls of a pitch black room"[106]. Translating without the flowery non-specifics, Fox uses the quantifications of his gestures - velocity and speed, and location of his playing - to enact complex, pre-recorded synth sequences, harmonic progressions, and tenor sax samples that modulate timbre based on those extracted features. He used what is known as an electro-acoustic hybrid drum set up, where the sensors are placed on plastic heads instead of mesh alternatives. The plastic heads allows for the timbre of the acoustic drums to resonate while the sensor blend these natural sonorities with and augmented, electronic sonic palette.

Kendrick Scott takes a similar approach with his own composition, EVOLve[107]. The composition uses poet Kyodo Willams's thoughts on empathy and love (which Scott remarks as the "same four letters of the word EVOLve" and the inspiration for the total of the composition) and its necessity for improving social relations in America. Scott adopts a different polyrhythmic approach during each stanza of the poem, but ultimately takes a minimalist approach in integrating the SSP into his set up. With the exception of intermittently triggering some lo-fi synth pads, Scott approaches SSP in a similar way that other, less sophisticated drum electronics would be used: as a trigger for a sample. One

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[105] Leah Mandel, "How Greg Fox Creates Worlds with His Drums," Fader, September 14, 2017. https://www.thefader.com/2017/09/14/greg-fox-the-gradual-progression-sensory-percussion-interview

[106] Dan Smart, "Greg Fox Announced New Solo Album *The Gradual Progression*, Shares New Video for *Catching an L*," Tiny Mix Tapes, June 22, 2017. https://www.tinymixtapes.com/news/greg-fox-announces-new-album-gradual-progression-shares-new-video-catching-l

[107] Tlacael Esparza, "A New Piece for Solo Drums and Sensory Percussion by Kendrick Scott, Sunhouse Blog, February 27, 2020. https://sunhou.se/blog/kendrick-scott-evolve

region of the floor tom is designated as the trigger for the next stanza of the poem, which would also cue Scott to change his rhythmic approach. He would change his drumming patterns over each stanza, either playing in rhythms of three, four, or five groupings, and alternates between those groupings based on the triggering of each incipient poem cue. Scott remarks on how triggering audio samples in a fluid way, on his own time, affords him the ability to approach this technology-mediated set up in a similar way in which he would interact with other musicians on-stage, observing that he can transition from section to section as quickly or slowly as he wanted. The SSP system affords him an elastic relationship to time, especially on the structural level of his compositions.

As the user base for SSP grows, so do the myriad ways in which drummers and multimedia artists combine the technology with other tools within their specific work flows. One such example is Colin Blanton, who is a part of the free jazz duo Brin. Along with guitarist Dustin Wong, Blanton recently released an album the features SSP being used in a slightly augmented manner, titled *Texture II.*[108] Blanton initially uses SSP in the manner similar to that of Fox and Scott, but routes the audio output of the SSP system into a different modular device called the *Monome Norns*[109]. The *Norn* is a compact, portable sound processor that runs scripts written in the Lua programming language.[110] Once scripts are run, any audio input into the system will be algorithmically processed, then

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108 Tlacael Esparza, "Electronic Free Jazz: An Interview with Brin on His New Album, *Texture II*" Sunhouse Blog, August 17, 2023, https://sunhou.se/blog/brin-texture-interview

109 Andreas Roman, "Monomer's Alternative Musical World: A Hands-On Creative Expedition with Norns and Grid," Create Digital Music. May 8, 2020. https://cdm.link/2020/05/monome-norns-and-grid-musical-review/

110 Ibid.

passes the resulting output. Blanton uses layered algorithmic processes to further manipulate the sounds that SSP initially generates based off of his own musical gestures.

Mason Self does something similar to Blanton, but with modular synthesis. Rather than running his audio into a different algorithmic audio processor, he uses the MIDI generated from SSP to control his own modular Eurorack. Instead of solely using the knobs and dials built into the analog devices, Self generates continuous MIDI values from the SSP that are then converted in control voltages to change modulation parameters on the synthesizer.[111] The work on his album, *Bow + Arrow,* is an example of combining both composition and improvisation within this hybrid digital-analog network.[112] Self will initially make a patch on his Eurorack, and maps the MIDI values and voltage controls to processing parameters. However, he also interjects himself into the modulating process, often using a combination of pre-composed parameters mapping and manually changing these relationship in real-time.

Other drummers have used SSP technology to control multimodal performance systems. Ian Chang converts MIDI values from SSP into the DMX protocol in order to control complex lighting systems and side-chaining techniques in real-time. His performance on *Spiritual Leader* epitomizes this approach[113]. Chang surrounds himself with an array of mounted lights, and each light is triggering based on the region on the drum he chooses to play. The brightness and duration of the each light is determined by the velocity of each

[111] Tlacael Esparza, "An Interview with Mason Self," Sunhouse Blog. July 26, 2019. https://sunhou.se/blog/mason-self-bow-arrow

[112] Ibid.

[113] Tlacael Esparza, "Open the Gates: Ian Chang's Creative Use of Sidechained Noise Gates with Sensory Percussion," Sunhouse Blog. August 3, 2023.

drum stroke[114]. Chang combined these lights with audio reactive visual that are mapped to the same gesture that control each of the lights. Philomène Tsoungui is a French technologist and percussionist who extends her use of SSP into virtual reality. For a recent performance at the *We Love XR* design conference, Tsoungui gave a multi-modal performance that centered the use of SSP attached to a hybrid electro-acoustic drum set.[115] A visual designer created four distinct scenes in virtual reality that Tsoungui manipulated in real-time by mapping the SSP data to certain elements within these virtual spaces. This included moving three dimensional objects around each of the scenes, using the SSP to transition from one design to the next, and generating temporary augmented visual elements intended to disrupt the natural and other worldly landscape the visual artists had constructed.

Where does the Cybernetic Trap Kit Fall Within These Practices?

The following chart contextualizes all of the aforementioned experiments and musical practices in relation to the Cybernetic Trap Kit and all of the domains its contents, technologies, and practices.

Project/ Figure	Acoustic Augmentation	Motion Tracking	Multi-modality	Sensory Technology	Virtualizing Drumset	Industrial Electronics	Computer Vision	Machine Listening	Live Sound Proce-ssing
Augmented Drum System									

[114] Tlacael Esparza, "Ian Chang's First Full-Length: Belonging," Sunhouse Blog, May 14, 2020. https://sunhou.se/blog/ian-chang-belonging

[115] Tlacael Esparza, "Philo Tsoungu Controls Worlds with Sensory Percussion," Sunhouse Blog, September 3, 2021. https://sunhou.se/blog/philomene-tsoungui-xr-event-wrap-up

Project/ Figure	Acoustic Augmentation	Motion Tracking	Multi-modality	Sensory Technology	Virtualizing Drumset	Industrial Electronics	Computer Vision	Machine Listening	Live Sound Proce-ssing
The Augmented Snare Drum	■	■							
AM MODE	■							■	■
LED Drum tracking		■	■	■					
Airstick Drum		■							■
Radio Baton				■					■
Virtual Drum Character Animation		■			■				
Virtual Drum SImulator		■			■		■		
Digitally Enhanced Drums	■							■	■
Sunhouse Sensory Percussion				■		■			
Augmented Drum Kit	■	■	■			■		■	■
Pathfinder	■	■	■			■			■
Death Ground	■	■	■			■			■
Torrrque	■	■	■			■			■
Icarus	■	■	■			■			■
Digital Wearables/ Drumming		■							■
Air Drum with Kinect/ Arduino		■	■						
Sensor-Based Drumming Capture		■		■					
Pragmatic Drum Motion Capture System	■	■							
Air Drums w/ Computer Vision		■			■		■		
Digitally Active Drum	■							■	

Project/ Figure	Acoustic Augmentation	Motion Tracking	Multi-modality	Sensory Technology	Virtualizing Drumset	Industrial Electronics	Computer Vision	Machine Listening	Live Sound Proce-ssing
Sensor Strategies for Capturing Percussion Gestures		■		■					
Roland SPD-30						■			
Alessis Electronic Drums						■			
Simmons SDS-V						■			
Toontrack Superior Drummer					■	■			
Steven Slate Virtual Drums Plug-In					■	■			
GetGood Drums Library					■	■			
XLN Audio Addictive Drums 2					■	■			
Mason Self				■		■			■
Marcus Gilmore				■		■			■
Kendrick Scott				■		■			■
Greg Fox				■		■			■
Colin Blanton				■		■			■
Ian Chang			■	■		■			■
Philomène Tsoungui			■	■	■	■			■

Table 2.1. A List of Related Projects, Compared to the Cybernetic Trap Kit

From the plethora of projects and research listed above, it is obvious that the mere combined use of computer vision, machine listening, and multimodality with the drumset is not some sort of singular distinction for the *Cybernetic Trap Kit.* However, the *Cybernetic*

Trap Kit distinguishes itself from the aforementioned projects by using transparent technologies of surveillance to preserve the act of playing the drums in a completely improvisatory context while also affording the performer to explore more elongated or alternatively expressive gestures. Based on the *Free Jazz Performance Model*[116] of Computer-Human Interactivity, this design consideration centers the compositional process around the performer itself, as their gestures become "the technical tool of communication and creative flow".[117] Thus, the system can be considered a performance-driven software program, as there is no anticipation or realization of any pre-programmed musical score.[118] Transformative response methods process the incoming audio signal from the acoustically augmented drumset by simultaneously measuring pixel-to-pixel differentiation in the gestural movement monitored in the incoming input matrix.

The ramifications of this design are by no means inconsequential to the experience of interacting with the system. Where the *DMI* for drummer Jim Black "leaves the mappings and sound design to the improvisers who need to maintain control of their idiosyncratic processes, the data required in the sub-matrix is routed to a specific (and singular) parameter, making the act of operating the signal processing within the performance a fully automated and virtual experience.[119] This eliminates any requirement of interfacing with a physical or prefabricated interface, as was the case with Pras's *DMI.*

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[116] Winkler, Todd. Composing interactive music: techniques and ideas using Max. MIT press, 2001.

[117] Mazzola, G., & Cherlin, P. B. (2008). Flow, gesture, and spaces in free jazz: Towards a theory of collaboration. Springer Science & Business Media.

[118] Rowe, "Interactive Music Systems"

[119] Pras, A., Rodrigues, M. G., Grupp, V., & Wanderley, M. M. (2021). Connecting Free Improvisation Performance and Drumming Gestures Through Digital Wearables. *Frontiers in Psychology*, 1001.

While the process of data acquisition and feature extraction is completely virtual, the experience of playing the drums can remain intact, even if the design of the user experience prompt the drummer to experiment with gesture. In contrast to the *Virtual Drum Simulator* or *Air Drums* projects, computer vision techniques are not used to entirely replace the drumset with a virtual facsimile of itself, nor it is meant as a practice replacement for the acoustic set, or to function as an educational tool for entry level drummers. Rather, that same transparency the computer vision tools provide in these projects functions as the same means to acquire gestural data in the *Cybernetic Trap Kit*, guaranteeing that the necessity of measuring the drummer's movement during a performance does not impede on the tactile sensation of playing the acoustic instrument, if the drummer so chooses.

It is also important to note the differences between *Icarus, Pathfinder, Death Ground,* the *Augmented Drumset,* and the *Cybernetic Trap Kit*, while still observing their salient similarities. The *Cybernetic Trap Kit* currently uses motion tracking techniques, while the *Augmented Drummer* uses a combination of contact microphones, and modified electronic drum triggers - the very design system that has been actively avoided during the development of the *Cybernetic Trap Kit*. There is also no presence of a competition in the *CV Drum Tracker*, nor is there a way of "dying," or "winning," winning the context of performing with the software. In fact, experiencing any form of resistance with The *Cybernetic Trap Kit* would be antithetical to the stated goals of the project.

It is more difficult to situate the *Cybernetic Trap Kit* within the practices of drummers who are using emergent - and mainly, sensory - technologies. This is because all of the aforementioned drummers have still retained their original creative practice, at least somewhat, intact. This is especially true in reference to how these musicians interface with the drums. Yes, there are various sonic augmentations being explored, and the SSP system affords them to extend their drumming gestures into multimodal territories, but what has not necessarily changed is the means through which these players control all of these outcomes. The same cannot be said for the *Cybernetic Trap Kit* . The means by which one processes their performance in real-time is virtualized, and most of the acoustic drumset has been translated into this new space as well. The *Cybernetic Trap Kit* requires a different gestural vocabulary in order to simultaneously play both the material and virtual elements that comprise its technological assemblage. This is a fundamental difference in the user interaction design and performance between the drummers only using the SSP in comparison to the combing it with the *Cybernetic Trap Kit*. The most similar practices to the *Cybernetic Trap Kit* are those that are involve in making virtual networks between the primary interface and the visualization of those gestural interactions. This includes the work of Philomène Tsoungui and Ian Chang, as their work and the *Cybernetic Trap Kit* are all centered around the idea of using a complex technological assemblage to create networked intermedia, audio visual experiences.

It is vital to understand the differences between the *Cybernetic Trap Kit* and other attempts to virtualize the drumset, especially in comparison to the commercially available tools discussed above. Most of the these tools, and certainly in the case of the Toontrack's

EZ Drummer 3[120], Toontrack's *Superior Drummer*[121], *Steven Slate Virtual Drums*[122], *GetGood Drums Library*[123], *and XLN Audio Addictive Drum 2*[124], these virtualizations take the form of Digital Audio Workstation plug-ins. These products are designed to make drum performance more efficient in music production practices. Consider the interfaces of the *Cybernetic Trap Kit* and Toontrack's *Superior Drummer* and *EZ Drummer 3.*

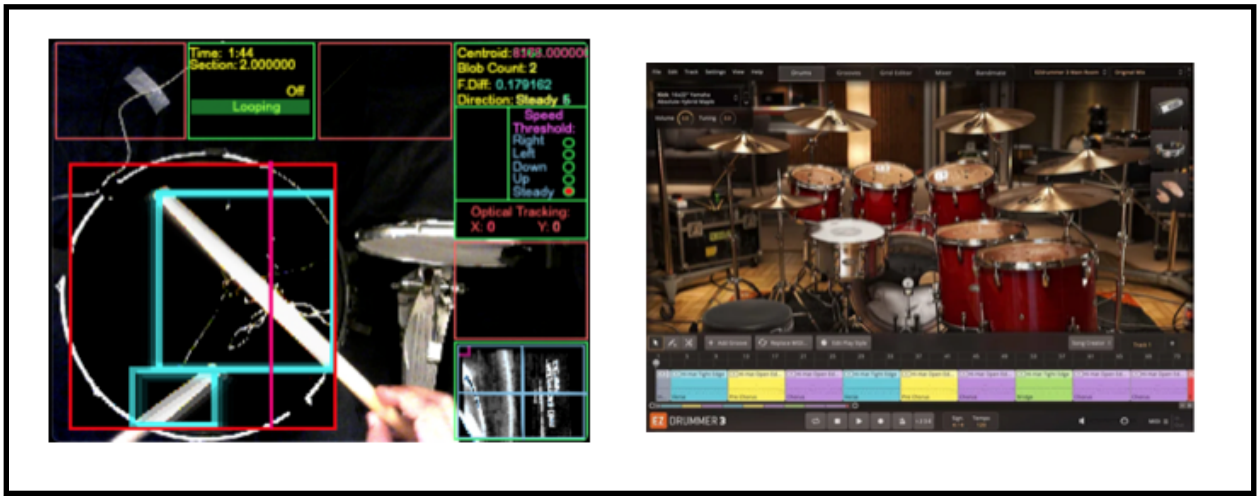

FIGURE 2.4. CYBERNETIC TRAP KIT AND SUPERIOR DRUMMER INTERFACES

A comparison between these two methods of virtualization will further contextualize the use of the term Virtual Augmentation to describe the *Cybernetic Trap Kit*. Both softwares are a form of virtualizing a traditionally acoustic musical instrument, but is

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120 "Meet Your New Drummer," EZ Drummer 3, May 6th, 2024. https://www.toontrack.com/product/ezdrummer-3/

121 "The Complete Drum Production Studio," Superior Drummer, May 6th, 2024. https://www.toontrack.com/product/superior-drummer-3/

122 "The Drum Sounds of Your Dreams," Steven Slate Drums 5.5, May 6th, 2024. https://stevenslatedrums.com/ssd5/

123 "Amazing and Incredibly Diverse Drums Samples," GetGood Drum Sample Library, May 3rd, 2024. https://www.getgooddrums.com/pages/about-us

124 "Experience Real Drums Played by Real Drummers in Your Music," Addictive Drums 2, May 4th, 2024. https://www.xlnaudio.com/products/addictive_drums_2

it at that point where their similarities end. The *Cybernetic Trap Kit* centers the drummer as an indispensable component to the processes of real-time musical production. It virtualizes many material components of the drum set, and in doing so, the interface is designed to act as a instrument for drummers to either use with the standard assemblage or as a completely new virtual means of accessing a modularized sonic palette detached from any acoustic materiality. In the case of Toontrack's *EZDrummer 3,* or the hubristically named *Superior Drummer,* the intention behind the virtualization is meant to replace the human drummer entirely. The beat-making bedroom producer can click on the drum set's virtual simulacrum to create a drum part all while bypassing the once essential musical labor provided by professional drummer. One of these virtualizations is aspiring to be an agent of creativity for actual drummers, while the other acts as a tool of efficiency. The *Cybernetic Trap Kit* can be thought of as a virtual augmentation of drumset performances practices, while the aptly named *EZDrummer 3* (and similar software) represents a virtual reduction of those same practices in the name of efficiency and cost-effective productivity. In the context of the *Cybernetic Trap Kit*, the word augmentation has multiple meanings. The use of emerging technologies centers the human in a mediation between the virtual and the material, augmenting their relation to the acoustic drumset and. These same technologies are also the means through which the drummer processes their own performance in real-time, resulting in a altered sonic profile referred to by many of the projects discussed above as Acoustic Augmentation.

CHAPTER 3: TRACKING THE PATH TOWARDS VIRTUAL AUGMENTATION

The desired outcome of the system is not focused on completing one particular piece of music, but on establishing a computational approach towards crafting an entire environment or infrastructure through which the combining of multimedia formats and multi-modal performance techniques could be achieved. The motivation for exploring the creative potential in virtual augmentation arose from an interest in programming software that could transparently integrate interactive computer music, real-time audio signal processing, and digital visual art with drum set performance, while simultaneously affording the drummer to reorient their gestural approach to playing the standardized drumset. This second consideration was crucial, as it provided the means to explore physically expressive alternatives for the purposes of processing both the sonic and visual elements in the system. With these considerations in mind, a camera or video seemed like an ideal candidate for programming a system featuring multimodal inputs and outputs. The same output from the camera could assume two crucial functions: to provide an effective and visual interface for the performer so that they formulate an aesthetic connection between the virtual and physical components, and to visually translate the way in which the performers navigated this virtual augmentation to observers. Additionally, the computer vision technologies are used to design a screen-based, 2D interface that functions as a repository and reflection for evolving embodiments in relation with the hybridized instrument.

Development Phases

The current design of *Cybernetic Trap Kit* is a result of an iterative process, one which can be separated into four phases. The first design phase was completed in late 2021. The second phase was completed in late 2022, the third was completed in June 2023, and the fourth was finished in March 2024, and the version used in the dissertation concert. As the following display of screen interfaces will demonstrate, there was a correlation between an improved understanding of motion tracking technologies and an ability to clearly define and communicate the system's features to the user.

Phase One

The performance interface of Phase One is displayed below.

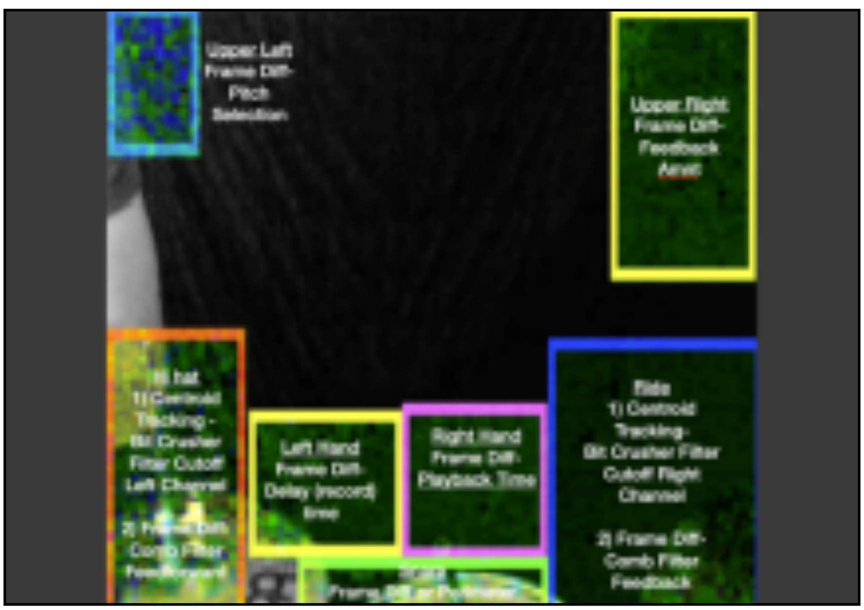

FIGURE 3.1. VIDEO SCREEN INTERFACE, PHASE ONE

The video feed is captured through a Logitech C920 Webcam, which connects to the computer through a USB-A adapter. Using a camera detached from the computer enabled the performer to position the camera where it could best capture their own body position without manipulating the angle of the screen. Four microphones are used to capture the audio of the drum performance: Shure SM57 on the snare, A Shure Beta 52a on the bass drum, and two AKG C414s as the Left/Right Stereo pair acting as the overhead mics for the entire drumset. Audio was sent through a Focusrite Scarlett 18i20 interface, then recorded into the audio inputs of Zoom Q8 Video Camera. The Q8 captures both the dry signal and audio processing, as well as the original feed of the drum performance without any of the visual processing. The purpose for this dual-recording is to compare the latency, frame rate and overall video quality of the processed visuals to the "control" recording on the Zoom Q8. The target frame rate for the video recordings were 30fps, with a sampling rate for all the recorded audio set to 48k. All audio and visual processing software was built in Cycling 74's Max/Msp~/Jitter, and used the cv.jit external library.[125]

The sub-matrices inside the larger image matrix were referred to as Target Sensors. The user was able to move four of the seven zones present in the camera feed: the Upper Left, Upper Right, Hi-hat, and Ride Zones. The user was not able to change the rate or range of their movement, but the Moving Target Zones could always be reverted to their original position.

Saturation effects were applied to each sub-matrix as a way to contrast with the grayscale video feedback of the entire camera feed. This made a clear distinction between the motion occurring inside and outside the specified target zones. The machine listening

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[125] Jean-Marc Pelletier, "Computer Vision for Jitter," Jean-Marc Pelletier Media Art, April 23rd, 2024. https://jmpelletier.com/cvjit/

techniques yielded amplitude tracking data that controlled the amount of feedback that was applied to the background video feed. The following image displays Phase One's control interface.

FIGURE 3.2. TARGET MAPPING CONTROL INTERFACE, PHASE ONE

Motion tracking techniques of Frame Differencing and Centroid Tracking were used inside the Target Sensors to control audio processing in the signal chain. These mapping techniques were programmed into the system, unable to be changed by the performer.

Sub-Matrix	Frame Differencing	Centroid Tracking
Upper Left	Pitch Select	
Upper Right	Feedback Network	
Hi-Hat	Feed Forward	Bit Crusher -> Filter L
Ride Cymbal	Feedback	Bit Crusher -> Filter R
Left Hand	Delay Time	
Right Hand	Playback Time	

Sub-Matrix	Frame Differencing	Centroid Tracking
Snare	Time Stretching	

Table 3.1 Camera Measurement Mappings, Organized By Zone, Phase One

Parameter mapping relationships could be established between the position of each Moving Target Zones and the gestures occurring inside of them. These relationships were referred to as Moving Target Mappings (MTM). MTM controlled the spatial and amplitude balance between dry and processed sounds. This was done by randomizing the position of the Upper Right or Upper Left Target Zones. Once this process is initiated, any movement of the Upper Right target zone along the horizontal axis controls the panning of four front speakers. While the horizontal movement controls the panning of dry and processed sounds, the vertical movement (when automated) manages the amplitude balance between the individual effects, which include the Comb Filter, Bit Crusher, and Multi-Tap Delays. This is done by dividing the overall horizontal and vertical movements of the Upper Right (relative to pixel location) by half so that the overall video dimensions can be split into four individual quadrants. Each of these quadrants are assigned an audio effect. Once the Upper Right Target Zone moves into a quadrant, its gain level increases, just as it will decrease to zero as the zone transitions into another quadrant. This causes a dynamically shifting balance between the different audio effects and the Master Dry Send.

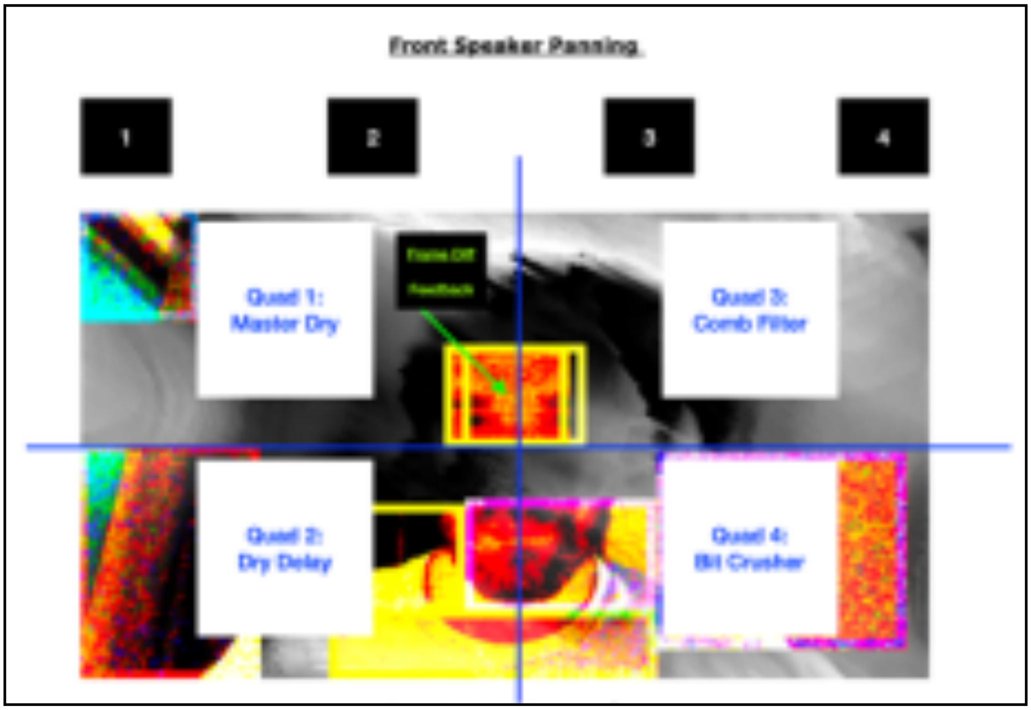


FIGURE 3.3. MOVING TARGET MAPPINGS DIAGRAM, PHASE ONE

Evaluation

While these mapping constraints yielded some interesting sonic results, the feature provided by them were a complete mystery to the user, which made them seem even more opaque to an observer. The photo above provides a diagrammatic aid to how these mappings worked, but the interface during performance provided very little instruction.

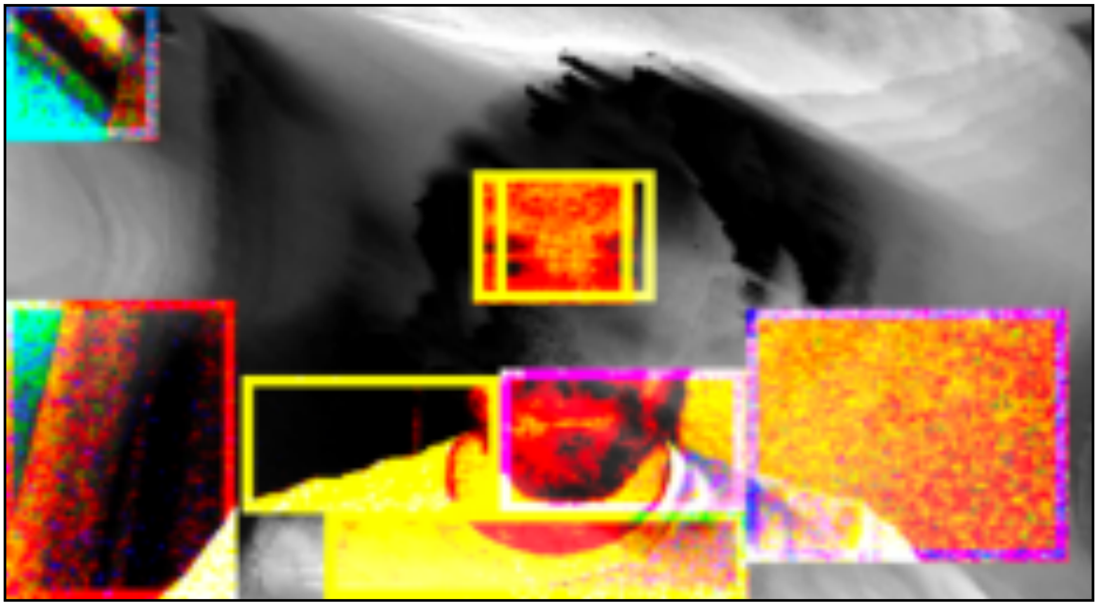


FIGURE 3.4. VIDEO SCREEN USER INTERFACE, PHASE ONE

There is no initial information provided on the user interface that indicates what these sub-matrices do, or how the user is supposed to interact with them. As a result, instead of interacting with the software as a musical counterpart the user has to develop these connections in real-time. While making connections between the gestures and sonic outcomes was supposed to be somewhat of an emergent process, the design simply proved to add to the difficulty of discerning the mapped relationships.

The system afforded the performer very little in terms of exercising their own creativity within the very stringent constraints imposed upon them. The Moving Target Zones were intended to extend the gestural possibilities at a drummer's disposal. However, since the gestural movement inside the sub-matrices was responsible for processing audio and not the movement of the matrices themselves, I was compelled to perform gestures that were completely separate from any physical motion required to play the acoustic drum set. This was especially true if I wanted to augment the instrument's sound in real-time.

This option to augment gestures was intended to be optional but by no means compulsory. There were far too many sub-matrices than were necessary, and the positioning of the sub-matrices made it difficult to expand gestural vocabulary beyond those motions inherent to playing the acoustic drums without a complete disruption of these drum-centric movements altogether. I was compelled to choose between one set of gestures or another. Furthermore, I was not able to designate any mappings between their own Moving Target Zones, gestures, and sonic outcomes. This proved to be too much of a constraint on a system which was capable of producing more outcomes than one specific mapping could possibly anticipate. In addition to a more flexible mapping strategy, more modularized processing software was needed to maximize the sonic potential of the system.

In summary, an ambiguous interface design lacking in any data or text-based information provided an interesting visual component, but it did not translate to the user having any sort of clarity in knowing how to interact with the software. The movement of the matrices produced too much of a game-like environment, where I felt like they were competing against the software instead of mediating through it. The time it took to discover the few features of the system was unnecessarily long, and perhaps impossible to do if the performer was not also its programmer and designer. The technological limitations of using only Frame Differencing and Centroid Tracking as the means for audio processing produced results that I deemed to be sonically unsatisfactory. It became increasingly apparent that the amount of motion tracking technologies in the system needed to be expanded while the interface itself needed to be more clearly understandable and interactive.

It also became evident that there was a need to test the software through performance during the design phase, as opposed to waiting until development had been completed. Many of the issues and limitations of the design could have been realized sooner if playing had been more integrated into the development process. The design in Phase One was largely completed before playing had ever commenced. This meant that my playing had to compensate for the limitations of the system. My musical vocabulary certainly changed, but it did not come about from anything resembling an integrative synthesis between the physical and virtual technological assemblage at my disposal. As a result of these shortcomings, many of the design choices that were made during this phase have been discarded. However, some of the design decision features have carried over to its current design model. The choice to differentiate between the matrix and the sub-matrix by outlining them with rectangles and using effects processing were both retained through each phase in development.

Phase Two

Phase Two has proven to be one of the most crucial in determining the future development and design of the software, and focused on providing clarity to the performer. Every sub-matrix was eliminated but one. No longer did multiple sub-matrices move across the screen, which eliminated the Moving Target Mappings from Phase One (along with the potential confusion that stemmed from their presence). The remaining single sub-matrix was still able to move around a section of the larger sub-matrix.

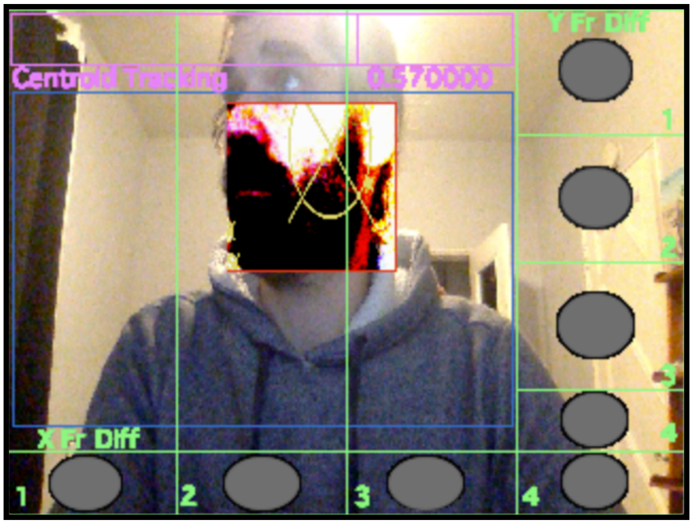


FIGURE 3.5 VIDEO SCREEN USER INTERFACE, PHASE TWO

The number of motion tracking technologies at the performer's disposal was expanded. These additions included Blob-Centroid Tracking and Optical Tracking. Rather than using Frame Differencing inside seven different sub-matrices, the performer could rely on other tracking techniques that provided more useful data for processing audio. Frame Differencing is effective for measuring extreme changes in motion on a frame-to-frame basis, but is not conducive for providing gradually changing data. In order to enact audio processing with Frame Differencing, either a very demonstrative gesture, long periods of complete inactivity, or increasing the distance between the performer and the camera feed, were required. Other techniques, such as measuring for concentrated areas of light inside the sub-matrix and tracking how these areas change over time, were more effective for generating data for processing audio over long periods of time. Switching to Blob-Centroid Tracking and Optical Tracking facilitated these subtleties in data acquisition inside the single sub-matrix, resulting in more fluid experimentation with gesture.

Frame Differencing was still used, although in a completely different manner than in Phase One. The video screen interface was separated into 16 sections (4 rows and 4 columns), all of equal size. Frame Differencing operations could be performed on each section. The incoming measurements were continuously evaluated against a set threshold, and virtual buttons were used on the video screen interface to indicate when a gesture exceeded this value. If the incoming motion exceeded the threshold, then the activity would trigger the process or event that was mapped to that particular region of the screen. For instance, Frame Differencing values on the rightmost column of the video screen would simultaneously trigger the playback of an audio file and switch between the primary camera view and feedback effect. The two leftmost, bottom regions triggered virtual synths.

The increase in motion tracking techniques enabled the performer to use the software to both generate and process sounds. Virtual synths could be triggered by Frame Differencing, routed to an audio device, and processed with a mapped parameter coming from one of the video modules. The system was designed to afford the performer to route any available video data point to a specified parameter in an audio processing device. Instead of having to discover these relationships in real-time during a performance, the user had to construct many of the constraints that they were to encounter. It became the standard practice to design this mapping procedure for each of the system's sound processing parameters.

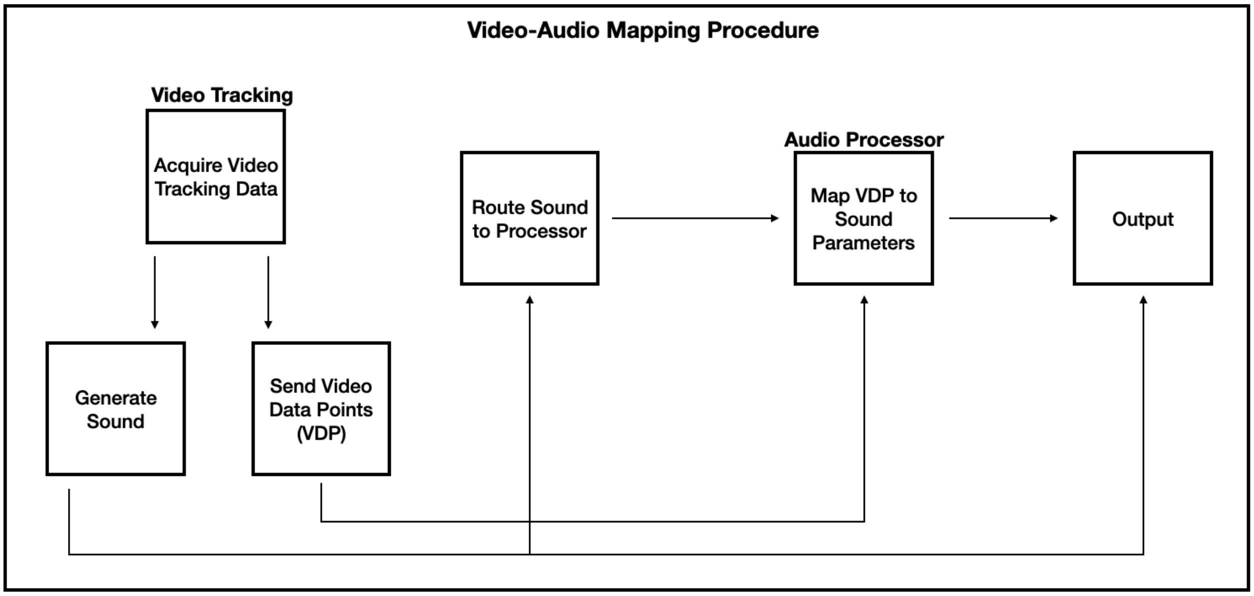
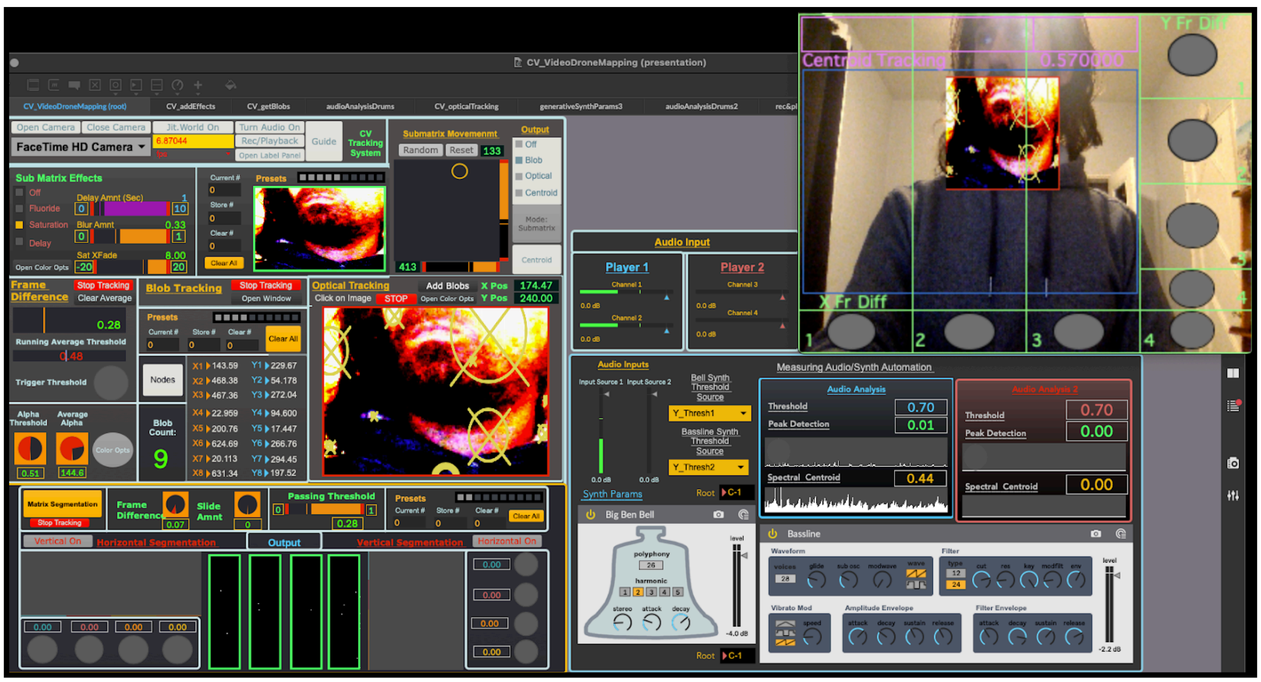


FIGURE 3.6. VIDEO-AUDIO MAPPING PROCESS PROCESS, PHASE TWO

Evaluation

The user interface on the video screen provided some salient measurements on the screen for me to reference. The options at my disposal were far greater in Phase Two than in Phase One. While there were some data points provided on the video screen, the software required far more monitoring than before. This meant that I had to perform with the interface on the video screen and simultaneously monitor the system's software in real-time. Experimenting with gestures became easier, but operating the software became increasingly difficult. Rather than freely playing the drums and interacting with the video screen, I often found myself thinking like a programmer or manager of the system during performance. Moreover, the buttons were placed in locations on the screen that made it nearly impossible to not trigger the processes associated with them. I could not simply put my hand into the sub-matrix to use these techniques of Optical Tracking and Blob Tracking without cueing a synth or triggering a visual effect. This made live performance quite difficult.

I decided that the complexities did not to be visible to the performer. Observing more than one screen during performance was superfluous and distracting. All of the information needed to monitor the data produced by the video-human interactions needed to be on the standalone video screen itself.



3.7. SYSTEM INTERFACE, PHASE TWO

Additionally, the system had no way to organize time on a structural level. There was no way to transition to different presets or reconfigure the signal chain without manually clicking on the screen. Clicking on the screen proved to be incredibly difficult to do during performance, especially when the user was monitoring video data points from the software interfaces and their own motion in the video-screen interface. From a design perspective, this needed to be rectified. This design was also limiting the sonic capabilities of the system.

At this point in development, the *Cybernetic Trap Kit* represented a potentially interesting tool for generating and manipulating sound, but could not be considered an automated system for organizing improvisation any further than to interact with it through one set of parameter mappings. While the tool provided me the ability of generating and manipulating sound, the constraints built into the system did not make it a particularly effective method for organizing time. Timed events were needed to both transition to a next signal chain of audio software, and to change the chosen presets for those modular devices. I would have to compose the structure by thinking of each signal chain as a section of the piece and map the video data points to audio processing parameters for each device prior to the performance. Once this macro form was established, I could then improvise my way through each section by interacting with the video screen alone, without the need to organize time or create parameter mappings in real-time.

Phase 3

The most technologically and conceptually consequential updates were completed during Phase Three. More motion tracking techniques were implemented into the design, yet the complexity involved in monitoring the software during performance was greatly reduced. The techniques of Blob Bounds Tracking, Blob Rotation Tracking, and Face-Tracking were added into the system. This data provided far more control to the user and more options for parameter mapping. These measurement provided the size, movement, and rotation of each blob tracked in the sub-matrix. The movement of this tracking data resembled the way a performer would move a dial or slider on an analog interface.

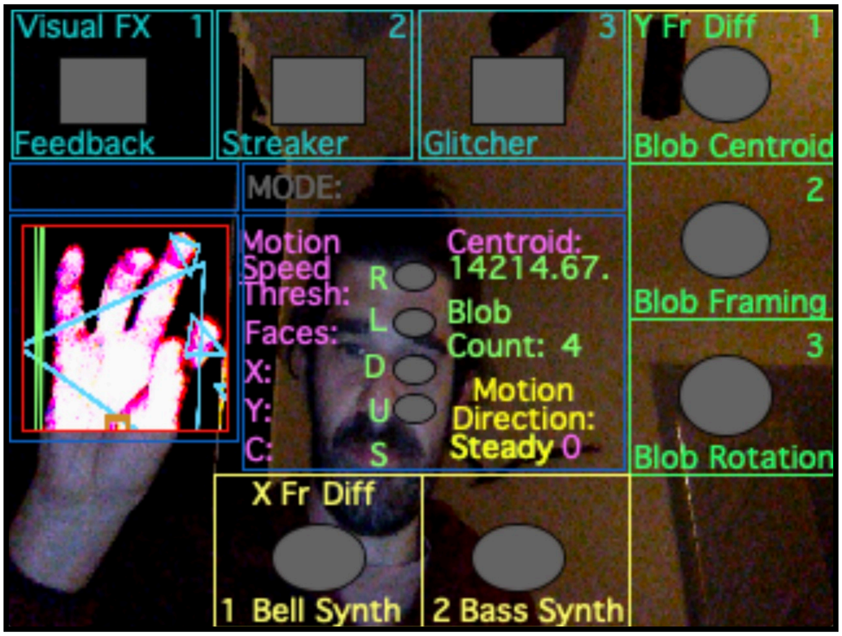


FIGURE 3.8. VIDEO SCREEN PERFORMANCE INTERFACE, PHASE THREE

Buttons that were impossible to avoid triggering in the previous phase were eliminated. The spaces on the bottom left and right side provided a point of entry into the screen without enacting any musical or visual outcome. The sub-matrix no longer moved at all. This was a feature that was rarely used, so it seemed somewhat superfluous to keep including it. Eliminating the movement of the sub-matrix meant that there was more space to include salient data points that needed to be monitored. Instead of having to reference an expansive, complicated piece of software during performance, the user is provided the information for nearly all the motion tracking techniques included in the design. The performer can also monitor the direction of their motion and how long they held steady in the sub-matrix. They are also able to switch between different tracking modes by using the frame differencing techniques on the right of the screen. These buttons (which represent sections of the screen) were previously mapped to trigger visual effects and spoken word files.

Three more visual effects were added to the system: a texture generator, a color streaker, and a video glitcher. The visual effects were still triggered by the same technique, but the buttons and regions that cue these processes are located at the top of the interface. These buttons are placed in the topmost section of the screen, which eliminated the possibility of the visual effects being inadvertently triggered. Situating these buttons at the bottom of the screen would make the user have to cross them to access any other part of the interface. This particular hindrance was discovered in performance during Phase Two and had to be corrected as soon as possible.

The regions that could trigger a function or feature through frame differencing have also been labeled, as is all the motion data in the middle of the screen. Each of the regions were assigned only one function. No longer do frame differencing operations in the one region control multiple processes. This was not the case in Phase Two, where the same regions were used to enact the spoken word files and virtual effects. Sub-matrix frame differencing was used to trigger the selection and playback of spoken word audio, with the filename appearing on the video-screen interface underneath the visual effects triggers.

The updated design of the video interface meant that the need to click or touch the software at all during the performance had been nearly eliminated. In Phase Two, the user had to monitor up to four video images at once. Providing so much information on the video screen interface meant that there was no need to monitor a huge piece of software while performing, leading to an improved and simplified user interface. This simplicity in design proved invaluable during performance. There was far less technology to be cognizant of while trying to play the drums, allowing the performer to simply focus on using the software as they desired during improvisation. No longer did the performer need to simultaneously assume the roles of "performing musician" and "system technician."

FIGURE 3.9. SYSTEM INTERFACE, PHASE THREE

Turning the system on was now an automated process. Every component of the screen interface was automatically rendered without user input. All the performer would have to do was simply instantiate the software and the program ran by itself. Other new features in Phase Three included the ability to use a video as input source instead of the built-in video camera feed, and having the ability to choose between three main output modes for the matrix feed: the primary camera feed (or movie file), the Frame Difference Mode, and the Effects Mode. The Effects Mode had four different settings unto itself, giving the user up to 7 different visual outputs to choose from. The sub-matrix feed could be switched between 5 different outputs as well. Each video processing module has its own user interface embedded in the system. In order to access the individual CV modules, the user simply clicks (or assigns a MIDI controller to open them) on each individual button. However, this information does not necessarily have to be monitored by the performer, especially during improvisation.

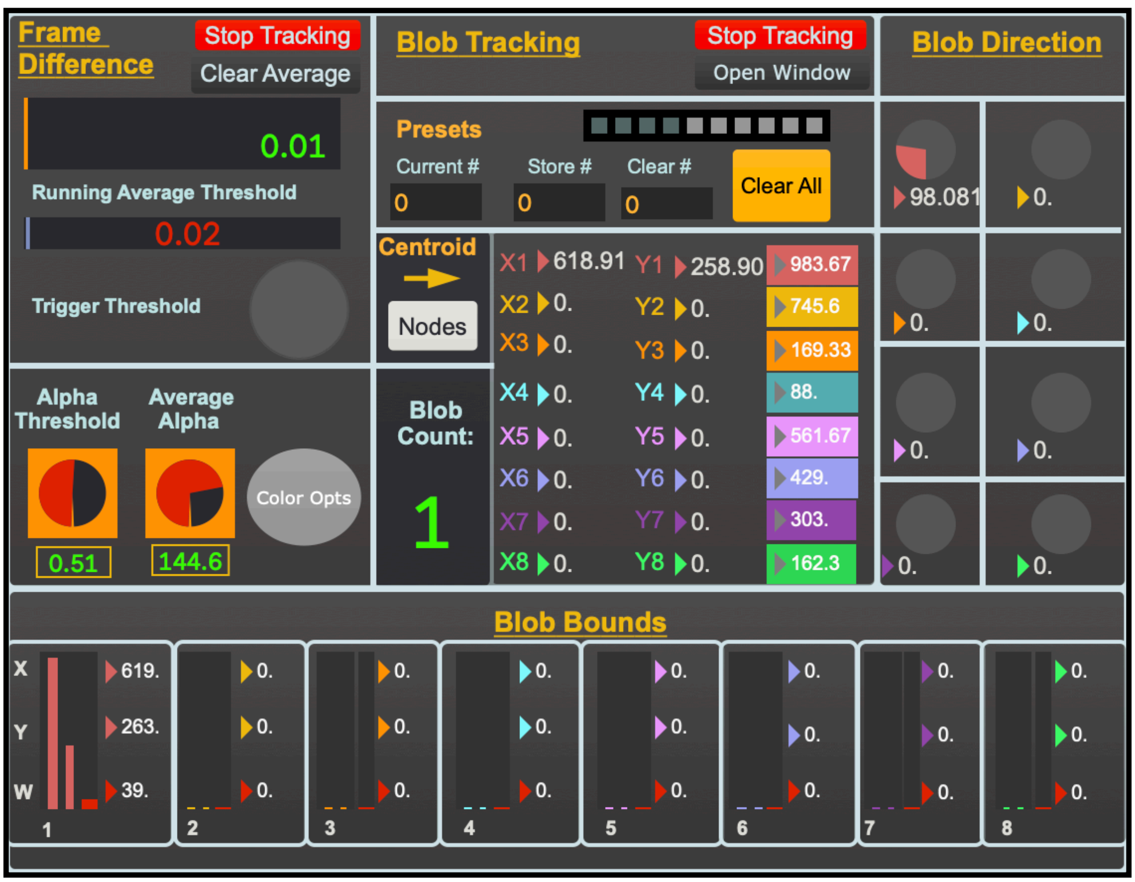


FIGURE 3.10. INTERFACE FOR CENTROID, DIRECTION, AND BOUNDS TRACKING, PHASE THREE

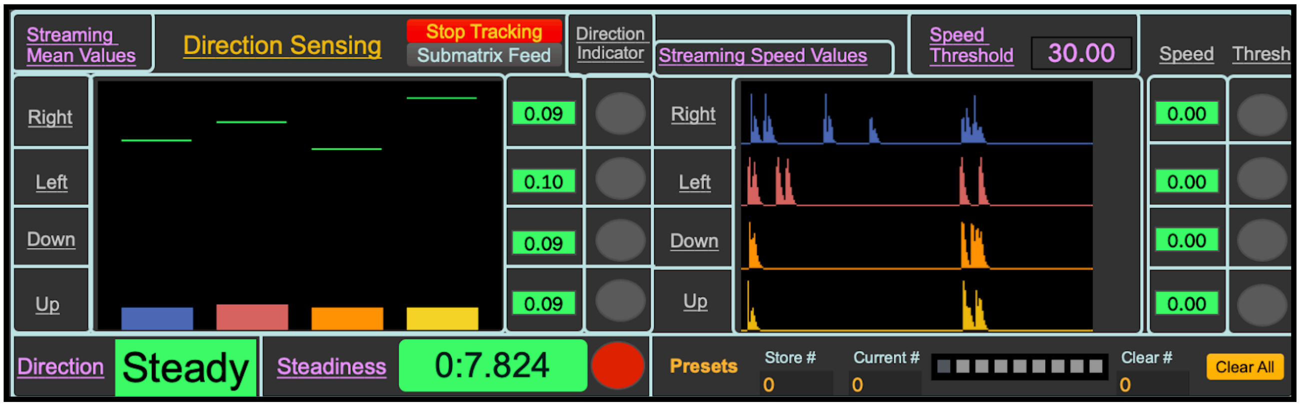


FIGURE 3.11. INTERFACE FOR DIRECTION SENSING AND SPEED MEASURING, PHASE THREE

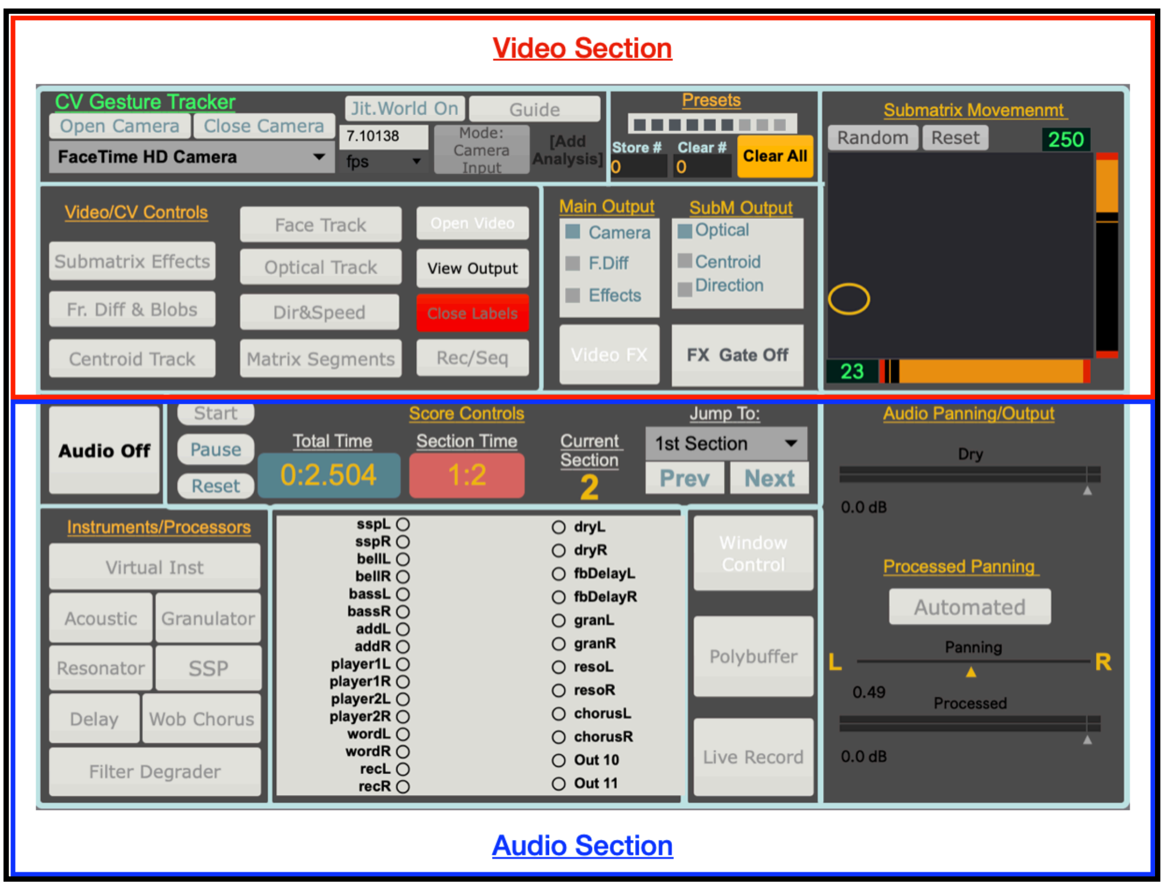


FIGURE 3.12. MAIN INTERFACE, SEPARATED BY VIDEO AND AUDIO FUNCTIONS

The system has been organized into two distinct sections. Any controls dealing with video input or data acquisition are located at the top of the interface. Any user-input that organizes audio processing is located at the button half. Additional modular audio processing devices were built and implemented into the signal routing system as well. In Phase Two there were two processors. Phase Three featured six audio processors, three virtual instruments, and inputs for up to four live musicians and an audio plug-in for Sunhouse Sensory Percussion. There was also the option to record the live input at any point in the performance, and to route the sequenced recording into any of the audio processing devices. Altogether, there were sixteen potential inputs and eleven possible outputs, plus panning options for stereo and quadraphonic spatialization.

The most substantial addition to the software in Phase Three was the automated score control and audio signal routing system. This feature afforded the user to create audio signal routings that would change based on an automated timer. Each section of the performance or piece can be thought of as individual signal routing. This timer feature manages the transition from one section to another without any user input during the performance. However, this automation is by no means compulsory, as the user does have the option to pause the timing of events, as well as skip to any of the pre-programmed sections (signal routings) during performance. Each audio processing module can be individually opened in the same manner in which each of the video modules can be accessed.

Evaluation

It is at this point in the development and creative process that the system represented a technologically-mediated strategy for what composer and professor Sandeep Bhagwati refers to as "comprovisation." He describes his neologism as

> An approach to creation in time-based arts predicated on an aesthetically relevant interlocking of context-independent and contingent performance elements. Comprovisation often uses unique constellations of oral, written, animated and interactive scores that can accommodate the scoring paradigms of many traditions and practices.[126]

Musical form was decided by the transitions between signal routings that I defined, but the interaction model between myself and computer within these sections was based on the me discovering these emergent gestural-to-sound (and visual) relationships through improvisation. It was at Phase Three in the design process that the *Cybernetic Trap Kit* represents an integrative approach to assimilating both its formal elements and indeterminate aspects into its technological infrastructure. The constellation of material that determined its multimodal output is embedded within the virtual machine itself. Far too often in electro-acoustic practices, the technology involved in the composition and improvisation is assigned a unidimensional, auxiliary, or tangential role in the creative process. An intention behind *Cybernetic Trap Kit* is to conceptualize a musical process, evaluate its outcomes, and ultimately, define a personalized style through a wholistic mediation with technology.

The design method described over the course of these three phases represents a procedural, systems-based, integrative approach to composition, where the comproviser is

[126] Bhagwati, S. (2018). Glossaire raisonné. *Circuit*, *28*(1), 15–22.

at once the programmer, designer, performer, listener, observer, and mediator of this hybrid environment. Such an orientation requires iterative prototyping, and the need to re-conceptualize the creative environment and the resulting aesthetic outcomes based upon the instant auditory and visual feedback yielded from the processes involved in this particular mediation with virtual and sensor-based technologies. Creative outcomes are realized by both the iterative nature of how design choices are made and the dynamic, unfinished programming environment from which this technological mediation takes place. Time is organized and sound is generated and manipulated within a system made from an open programming environment (Max/Msp~/Jitter), not a Digital Audio Workstation. To hear the outcome of my design choices, I do not have to play back a virtual tape machine, but have to rely on recursive operations that organize the playback of musical ideas. Even the recursive operations controlling the processes have to be determined and built by the musician/programmer themselves. Observing musical and visual processes happening right at the point of programming changes the way that I evaluate and respond to the last decision that was made. This process is a perpetual one. The way time becomes organized and how sound is generated feels systematic in preparation, yet dynamic in performance.

Phase 4

Phase Four featured a complete and comprehensive upgrade to the entire system, performance interface, and by extension, the user experience. The user interface was altered in appearance and design, and was mean to better emulate the anthropocentric direction undergirding the intended experience of the interacting with the system, and was completely rearranged so that the data and its labelling were cordoned to the edges of the screen. This enabled the expansion of the sub-matrix in the middle of the screen, covering the entire surface of the snare drum - the central focus of the standardized drum set interface. The middle of the user interface was now the main component of interaction, as if afforded continuous control of processing while every other sub-matrix on on the periphery were used to trigger discrete processes. Very little of the screen is not utilized for some type of user interaction; I can enter into almost any region of the screen to process their own live or recorded sound, or to instantiate the playing of virtual instruments.

The user-interface is far more elegant, and more importantly, mimetic to the instantly recognizable drumset interface[127].

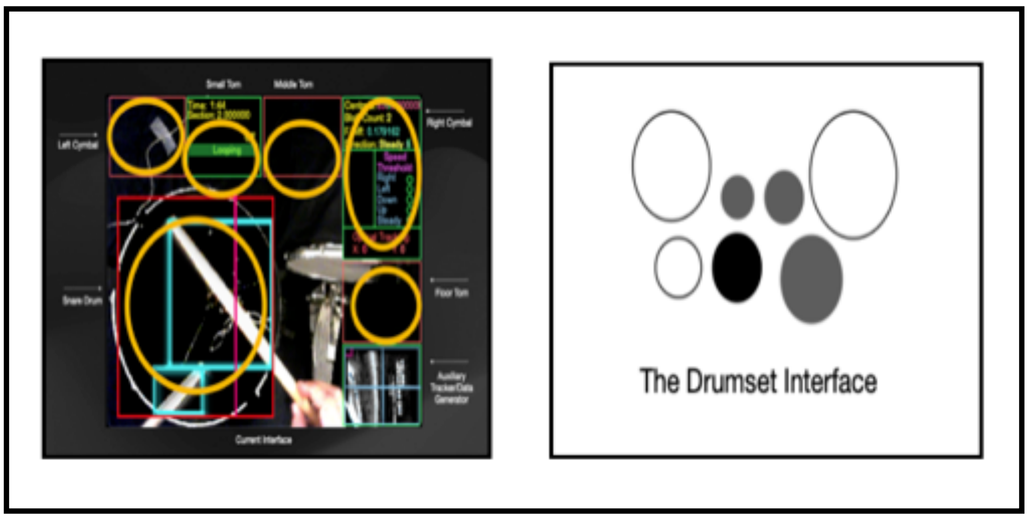


FIGURE 3.13. THE DRUMSET INTERFACE, APPLIED TO THE CYBERNETIC TRAP KIT

From a design standpoint, the difference between Phases Three and Four is readily apparent.

[127] The orange circles are not a part of the interface. They have been superimposed on the interface to demonstrate how these squares and their positioning around the screen reflect the interface of the standardized drumset.

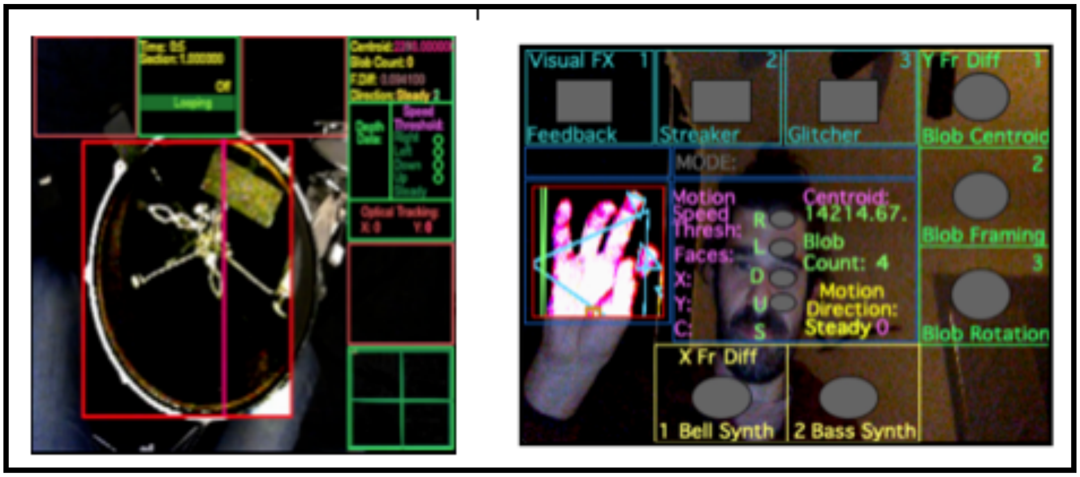


FIGURE 3.14. A COMPARISON BETWEEN PERFORMANCE INTERFACES, PHASES 3 AND 4

The sub-matrices at the bottom of the screen were eliminated. Prior to their erasure, these sub-matrices caused significant issues in the user being able to enter the interface without triggering any of the processes mapped to respond to the activity within these regions. Their inclusion also limited the size of the primary sub-matrix meant for continuous control and parameter mapping. The smaller size directly correlated with the limited expressive scope of the gestures occurring within it. Expanding this size (which is related to the elimination of the sub-matrices on the lower part of the screen) is one of the most consequential design decisions in terms of making the interface reflect the drumset interface.

The elegancy of the interface can be attributed to the elimination of the inner gray shapes housed inside the larger sub-matrices. These were not only redundant, but distracting and somewhat confusing when I performed; they were intended to be indicators for when I entered these regions, but that was not readily apparent. Instead, the sub-matrices would just light up the same color of their border, only with slightly less opacity. This led to another consequential development of the interface. The Computer Vision data and their labels were able to be positioned onto top of the regions which previously contained these gray, ambiguously purposed shapes. All of the information that was previously located in the middle of the screen essentially made the middle of the interface dead space for user interactivity and data generation, which, in retrospect, made very sense considering the intention was to virtually recreate the acoustic drumset interface. CV data was positioned on the upper right part of the screen. Additionally, automated score components were now added to the upper middle section of the screen, and includes the following:

1. Whether audio is being recorded into the buffer, looping from the buffer, or if live sound processing is being used.
2. Recording state of the buffer.
3. If a recording is looping, the current playback point in the buffer.
4. The current section of the composition.
5. Amount of time elapsed since the start of the automated score control system.
6. The name of any audio file that is triggered to play, including its duration

The CV data on the upper-rightmost section of the screen displays the following information:

1. Spectral Centroid Tracking Value,.
2. Amount of Blobs being generated in the primary sub-matrix.
3. Direction of the motion in the primary sub-matrix.
4. Running value of frame differencing (amount of activity relative to the previous frame) in the primary sub-matrix.
5. Speed of motion relative to current direction.
6. Optical tracking positional values.
7. Perimeter sensing/ depth data - if the user has entered the primary sub-matrix and the degree to which they've entered it.

The snare is the central component to that interface, so it made sense to center the sub-matrix primarily responsible for continuous processing on top of that drum. That sub-matrix could also be moved to account for each drummer's unique positioning of the snare drum. I could also move sub-matrix to the left of the snare as well, which would afford them to play the drum without automatically processing those gestures associated with that performance.

As previously stated, the secondary sub-matrices at the border of the screen were designed to trigger discrete events to occur. There is one exception to this: the bottom right corner of the screen is another region for continuous control. In Phase Three, optical tracking technology is implemented in the system, but layered on top of the blob centroid, rotation and bounds tracking that is used asa the primary data for continue control and digital signal processing in the primary sub-matrix. This layering of so many CV technologies proved to be too complex and laborious to use. That is not to say that digital musical instrument controllers should not require rigorous practice to realize their full expressive potential, but the design of these experiences should center music-making as the focus of these interactions. If the controller proves to be excessively difficult, then the user is not so much focused on exploring any complex sound to gesture relationships that may exist and is taken out of this creative consciousness and into a state of simply figuring out how the tool works. Optical tracking technologies were displaced from the central, primary sub-matrix and relocated to the bottom right sub-matrix, affording the user to simultaneously access both sub-matrices for continuous control.

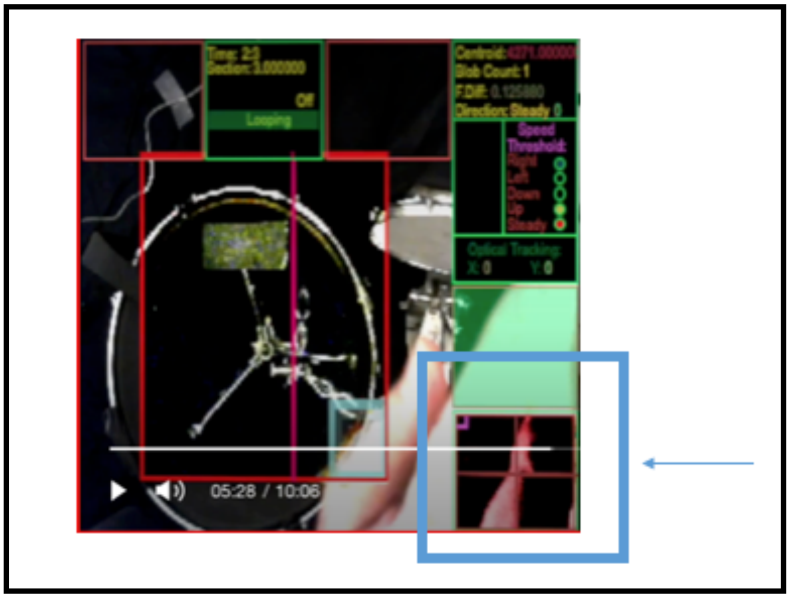


FIGURE 3.15. OPTICAL TRACKING COMPONENT ON PERFORMANCE INTERFACE

There are two methods, or modes, of using the optical tracking sub-matrix: automatic and discrete:

1. Automatic Mode: This is the default setting. Similarly to the automatic continuous blob tracking in the primary snare drum sub-matrix, any activity within the OT region tracks the largest spectral centroid. The exact center of this centroid is graphically represented by a small square that moves as activity in the sub-matrix changes. The exact center correlates to a pixel on the Y and X axes of the sub-matrix. The values will be from 0—320 on the X axis, and 0-240 on the Y axis. When no discernible motion in the sub-matrix is detected then those running values immediately go back to 0 and 0, which maps to the top left corner of the sub-matrix.

2. Discrete Mode: Instead of automatically using centroid tracking, the user can click on any part of the OT region and square indictor will automatically move to

that position. The user can then use this position as a starting point and continuously move the graphical indicator around the sub-matrix. If the indicator is moved to the edges of the sub matrix - the values ever reach 0, 240 on the Y axis, or 320 on the X axis - then the values default back to 0-0, the upper left.

In addition to the two modes, the OT sub-matrix was split into four regions, as shown below:

The regions were labeled one through four, starting clockwise from the upper left. The X and Y values were divided in half and logical operands were used to determine which of the regions that the indicator was in at any given point during tracking. The sub-region within the sub-matrix would light up to indicate that activity was being tracked within it. This could then be used to assign optical tracking to control audio or visual signal processing specifically mapped to activity the occurs within a particular sub-region of the sub-matrix. This design in intended to be a method of combining event triggering and continuous control capabilities.

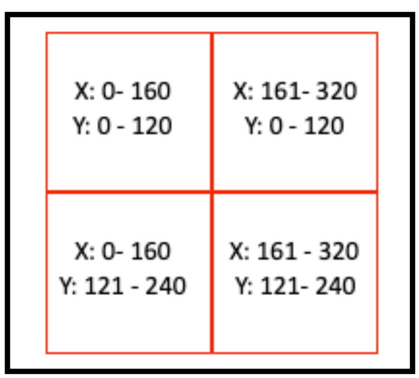


FIGURE 3.16. OPTICAL TRACKING MATRIX QUADRANTS

Combining event triggering and continuous control, as well as the separating the optical tracking from the rest of the motion tracking technologies, is incredibly effective for having one matrix generate sounds while another one processes them. To provide a more concrete example of this technique, a user could use frame differencing technology in the other sub-matrices that border the interface to trigger a virtual instrument to play, while the automation mode implemented in the optical tracking sub-matrix could route the pixel values from the X-Axis and map them to control the panning of those sounds. Another example would be to use the blob tracking in the snare drum sub-matrix to process a recorded performance while simultaneously controlling the filter cutoff frequency with the X-Axis values and gain level with the Y-axis values generated by activity within the optical tracking sub-matrix. I consider this a new form of digitally-mediated drumset independence, and will delve into these performance techniques in greater detail in the *Developing a Personal Performance Vocabulary* section.

When the user enters this region, their activity its saturated in a color, distinguishing motion within the sub-matrix from any gestures occurring outside of it. These colors gradually change over time, as does the border of the sub-matrix. This saturation technique is similar to the effects applied to the primary snare drum sub-matrix.

Apart from the newly designed optical tracking sub-matrix, the primary snare drum sub-matrix now includes an additional motion tracking feature: Depth-Data Sensing. This is a technology that can sense the degree to which one has entered a defined boundary, or border. The defined border is established as the bottom of the snare drum sub-matrix. The further away the user's tracked motion deviates from this border, the deeper their positioning inside the sub-matrix. This technology generates a continuous control value, but those running numbered are also sent through algorithms that categorize the depth level into three states: near, middle, and far away from the defined border.

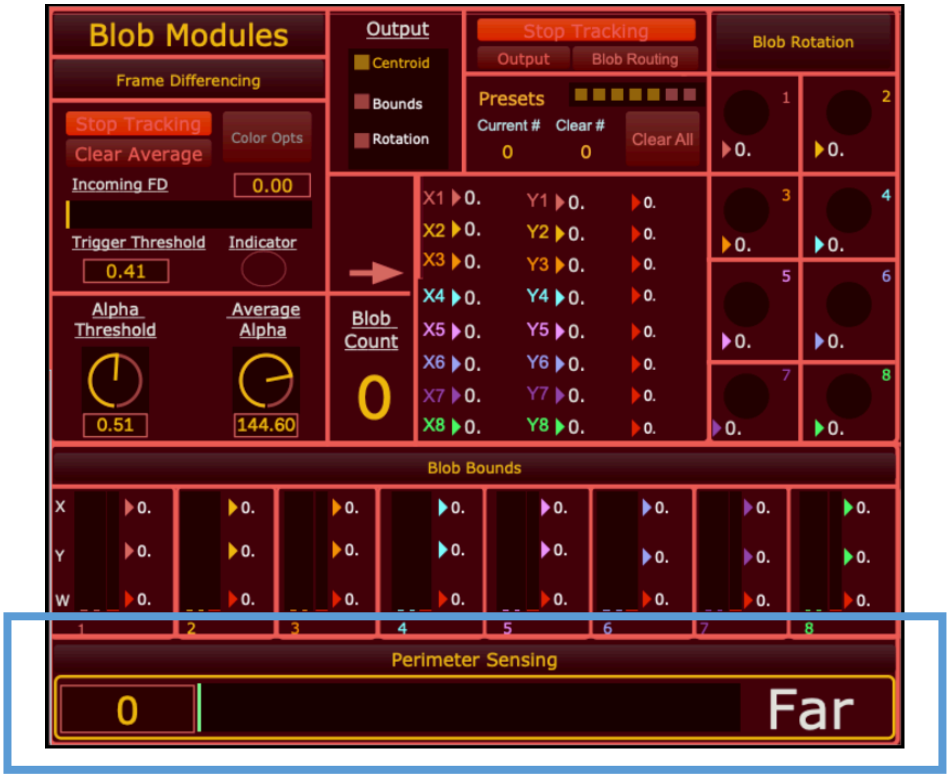


FIGURE 3.17. DEPTH DATA SENSING FEATURE

The system interface has been updated as well. It accounts for the system's expanded signal routing capabilities and the flexible automated score control options. The user can save signal routings as presets and access each of them in a drop-file menu, effectively making a whole set list of pieces. Each piece can also have its own durations - something which was not possible in easier phases of the software's development.

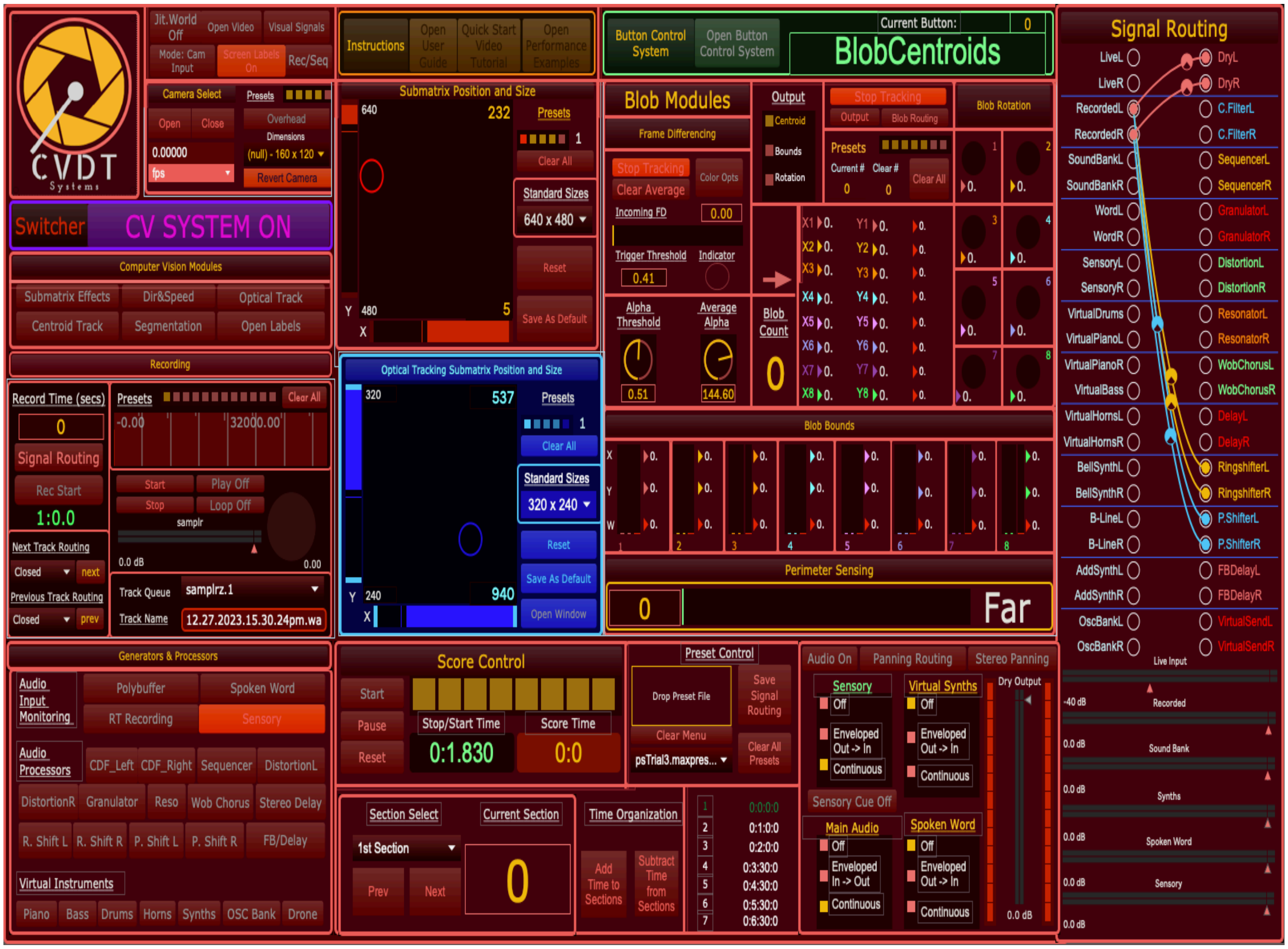


FIGURE 3.18. SYSTEM INTERFACE, PHASE 4

There are many other changes to the system interface, which are listed below:

1. The system now has a state switch - a way to control all of the CV tracking capabilities just by pressing a MIDI foot pedal.

2. The optical tracking sub-matrix can also be moved to a different location on the user interface (located in the blue area of the interface).

3. There is also a button control system connected to an external MIDI controller. Since every modular audio processor, physically-modeled virtual instrument, and CV module are not visible to the system interface , the user can now access these embedded

components by pressing on a MIDI controller button. This provides the user to, if necessary, access any of the embedded patches in system during or prior to performance

4. The inclusion of the live recording feature, located on the left side of the screen. The user can record as many tracks during live performance that they want, and can access each of them for playback.

5. Audio/visual output automatic recording. When the score control system is turned on the performance interface and the audio output is automatically recorded onto the user's hard drive.

As it has been demonstrated in this chapter, the *Cybernetic Trap Kit* contains within it a litany of system components, all of which are necessary to control how audio signal routings change, sounds are generated, and time is organized. Operating the system requires a high degree of technological literacy and the ability for the drummer to simultaneously play their instrument while monitoring a machine. Moreover, the system was designed to play one composition. The last section detailed how the automated timer controls at what point in a given performance the system's current signal routing transitions to the next one. There are a maximum of eight different routings (and the amount of time it takes to cycle through them) one can specify as a particular preset, which can be recalled at any point in a drop-down file menu. This function, combined with mapping the motion tracking data to specific sound processing parameters in the modular audio devices, represents the composition component of the system. The duration of a composition - and each section (signal routing) within it - can be specified, but in order to change to a completely different preset a performer would have to manually select one.

Furthermore, any process that controls the timing of events would also have to be reset and certain audio processors would have to be turned on or off, depending on the new routing specifications. With this in consideration, it becomes apparent that there are layers of operations to manage during a performance. As tedious as the performer would find it to accurately modify so many aspects of the software during a performance, it would be equally distracting for the audience to witness them stop playing in order to manually change so many components of the system.

These unintentional system constraints presented a logistical problem when the goal was to play a whole concert that featured the Cybernetic Trap Kit on every piece. They necessitated an additional level of programming that enabled the perform to automatically trigger a number of key functions to happen in sequence, just by executing a single keystroke:

1. Selecting a new system-wide preset, which included instructions for signal routings, the length of the score for each section and specified parameter mappings.
2. The opening and closing of different audio signal processors (turn them on and off as well).
3. Resetting the automated score controls.
4. Turning CV modules on or off.

The seamless execution of these system-wide resets became a chief concern during my concert. I did not want to have any lengthy periods of silence occur during the concert's duration, nor did I have the amount of time necessary to train someone else to learn how to operate the system. These additional instructions were able to be cued by the drummer simply by pressing a key on a MIDI controller, thus eliminating as much operational responsibility as possible during the performance. These additional features also facilitated a whole set of music to be played without the need to stop and reset each part of a complex system.

Since these considerations have more to do with sending signals to control other signals than specifying the granular sonic outcomes I refer to compositions made with the Cybernetic Trap Kit as a *routing schematic*. This phrase more accurately encapsulates what the system's user is actually tasked with doing before a performance (when the system starts its timer), and what steps need to be taken in order to ensure its seamless execution. Unlike many other musical compositions, these signal routings do not contain any inscribed meaning associated with them that exists apart from the performance. More vital to the musical efficacy of the software than the signal routings themselves is the user developing a refined method of interacting with the interface in order to generate and process sound. These skills exist outside the literacy required to program and design the system, and center one's ability to develop an augmented gestural vocabulary that combines drumset performance motions with two-dimensional screen-based interaction. Otherwise stated, it is the combination of system design and the manner in which the drummer interacts with its components and their instrument that provides the semblance of compositional structure to this music.

The following section will detail how I went about developing a gestural interaction vocabulary with the *Cybernetic Trap Kit*. This vocabulary explored the sonic possibilities of the software and led to the realization of different interaction methods, the combination which subsequently gave my performance compositional structure.

Developing a Personalized Vocabulary

Paths of Motion

The first step-in the process of developing a hybrid gestural vocabulary with the *Cybernetic Trap Kit* is to recognize the physical differences between playing the drumset and interacting with a two dimensional screen-based interface. When playing an acoustic drum, most physical motion is vertical. This is because each drum stroke is a two step process, respectively known as the *preparation* (and upstroke before making contact with the drum surface) and the *rebound,* which allows the drumstick to move back to its starting position by its own volition.[128] And of course, the force and velocity applied to these strokes affect the volume of the acoustic drum. The distance from the sticks to drum head plays a crucial role the amount of volume that is produced. The motion involved in a drum stroke occurs in three-dimensional space. By contrast, movement with most touch-screens or screen-based interfaces relies on only two-dimensional movement.

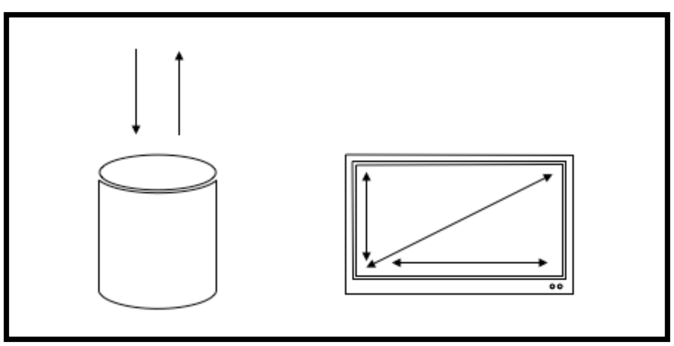


FIGURE 3.19. HORIZONTAL AND VERTICAL GESTURAL MOTION

[128] Dahl, S. (2011). Striking movements: A survey of motion analysis of percussionists. *Acoustical science and technology*, *32*(5), 168-173.

These different motions are separated in the image above, but during a performance, the screen is overlaid above the snare drum, as opposed to being placed along side of it. This allowed for the drumming motion to be tracking in real-time, but to process this incoming sound the performer would have to use more elongated, sustained, and somewhat circular motion when interacting with the two-dimensional interface.

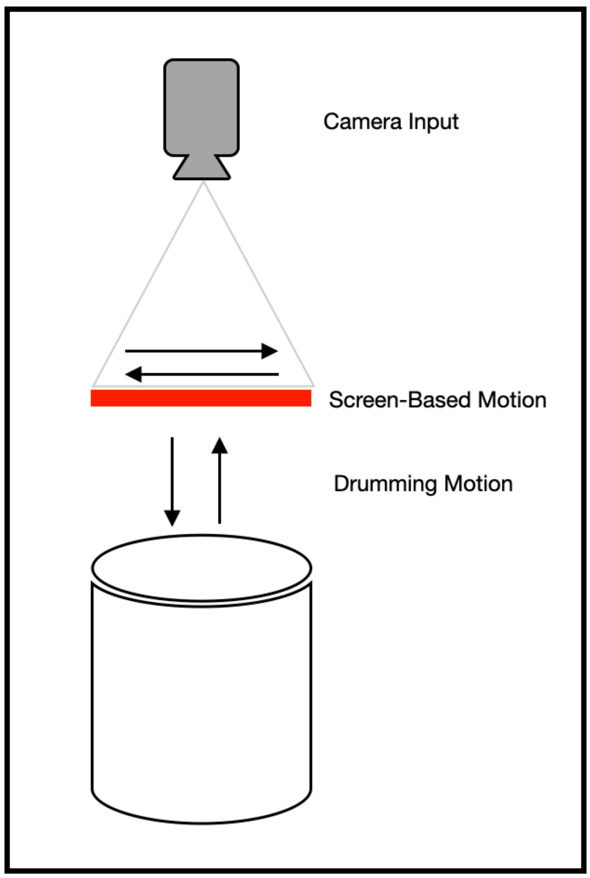


FIGURE 3.20. BOTH GESTURAL MOTIONS, APPLIED TO CYBERNETIC TRAP KIT

My approach to interacting with this assemblage was to come up with a new form of drumset independence, one which combined traditional drumming movement with the side-to-side motion required to interface with a video screen. In drumset performance, the term *independence* describes the ability to control multiple limbs at the same time, often performing these rhythms on different instruments or playing surfaces. In most circumstances, these rhythms are played at the same tempo but at different points in time, causing a layered, syncopated density. The physicality of this technique requires drummers to execute a wide array of rhythmic patterns with stylistic accuracy and fluency, and to do so with particular coordination, dexterousness of touch, and musical sensitivity. During the execution of these complex patterns that derive from drumset independence, overlooked is the possibility that the functional (and aforementioned) paths of motion used to execute these layered patterns could alternatively be leveraged to sonically process a live performance in real-time. Additionally, interfacing with the screen could be used to generate new sounds, toggle processes on and off, and display motion tracking information salient to the parameter mappings created in the software. This temporally elastic relation to their own performance affords the drummer to further manipulate and access sounds by using expressive gestural motions that exist in contrast to the functional movement associated with solely playing an acoustic drumset vocabulary.

This hybridized drumset independence between vertical drumming motion and horizontal, screen-based interactivity, combines the drummer's gestural vocabulary from the instrument's acoustic timbre and material dimensions with the fluidity of the virtual space. This extricates drummers from relying on learned rhythmic patterns, affording them to center their attention on deriving trajectories of motion intended for the explicit purposes of generating sustain on an instrument whose natural sonic profile mainly consists of short, densely layered and repeated impulses.

There is a feeling or presence of material resistance that plays an important role in shaping a drummer's physical relationship to the acoustic instrument. This resistance is essential in realizing one's expressive potential on the drum set. Developing a personal style with the abstract drumset interface is, in part, determined by the way a drummer navigates the inherent constraints that this physical resistance imposes.

That same resistance is nonexistent in virtual environments. It is often argued that the expressive shortcomings of digital or virtual instruments are as a result of the absence of any physical resistance. Emergent technologies, particularly those embedded in virtual forms of musical instruments with a long history of performance, often have a rigid or brittle quality to them. These qualities often making the users conform to factory-installed settings, which would have a direct effect on the sound of their music. A rigidity in the technology results in fewer creative outcomes.

A historical example of this tendency in digital instrument is the Yamaha DX7, one of the very first commercially available digital synthesizers[129]. While a great technological achievement made possible by John Chowning in the 1980's at Stanford University, the synth was incredibly difficult to program, which made cultivating a unique sonic identity on the instrument particularly challenging.[130] As a result, many of the world's most visible Pop

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[129] Lavengood, Megan. "What makes it sound'80s? The Yamaha DX7 electric piano sound." *Journal of Popular Music Studies* 31, no. 3 (2019): 73-94.

[130] Ibid.

music stars in the 1980's used the thirty-two factory-installed presets, yielding a largely homogenous sonic profile that instantly identifiable.[131]

Electronic drumset technology is no exception to this observable lack of physical resistance during its historical development, and many that attempt at seriously engaging with these these hybrid instruments share negative claims. One of the most persistent criticisms towards electronic drums is the lack of physical resistance many experience when playing on mesh heads, resulting in a loss of touch and ability to transfer their acoustic vocabulary to this new version of the instrument (cite). The DX-7 and the Roland V-Drums (as an example of electronic drums) are still physical instruments, meaning that musicians will still experience some of sort of physical resistance while interacting with them. The interfaces of these instruments looked familiar enough to its acoustic piano or the drumset antecedents for musicians to transfer their musical knowledge. Nevertheless, while these these new instruments that afforded musicians a contemporary sound palette, the brittle and rigid qualities associated with technology at its nascent stages compelled performers to change their gestural vocabulary in a way that has never been fully embraced by many.

[131] Interestingly enough, the brittle an rigid qualities intrinsic to these digital instruments are the reason why so much music that is algorithmically generated with artificial intelligence today reflects a a sounds associated with the electronic music of the 1980's - the early 2000's. This rigidity in technology transferred into a more grid-like relationship to tempo and groove, spurned on by the popularity of drum machines in all kinds of popular music genres. The changes in performing with these digital instrument eventually led to a generational change the way music was heard. This grid-like treatment to tempo, repeating drum grooves, and the use of timbres that were embedded into presets on the digital keyboards, are far more easily to quantify - which is to say, recognizable by and reproduced with a computer. A listen between a computer's attempt to replicate the subtleties of an acoustic jazz trio performance compared to the creation of an electronic music soundtrack excerpt will bear this out. For profit, A.I.-driven music creation companies like Boomy, AIVA A.I., and Amper do not even offer jazz as a genre option to its customer, and rarely offer classical music options as well. The best that may be offered is music that features the instrumentation within those styles within a completely different genre. With that as context, it should be hardly surprising that the music a computer is currently able to most easily and efficiently replicate derives from sounds that were produced by computers in the first place.

A completely virtual screen poses absolutely no resistance at all. Knowing this to be the case, I decided that embracing the paradoxical constraint of there being no physical resistance meant that I had to find a method of using motion that could be used to interact with the screen that would have some semblance of familiarity to playing the drums. This posed a significant challenge due to the vertical nature of most drumset motion. However, there is one somewhat familiar playing technique on the drumset that does utilize vertical motion: brush playing. Brush playing is a technique performed primarily by jazz drummers that involves the use of brushes being pressed upon the drum along a horizontal plane. This technique usually requires some sort of circular movement in one hand while the other improvises other trajectories.

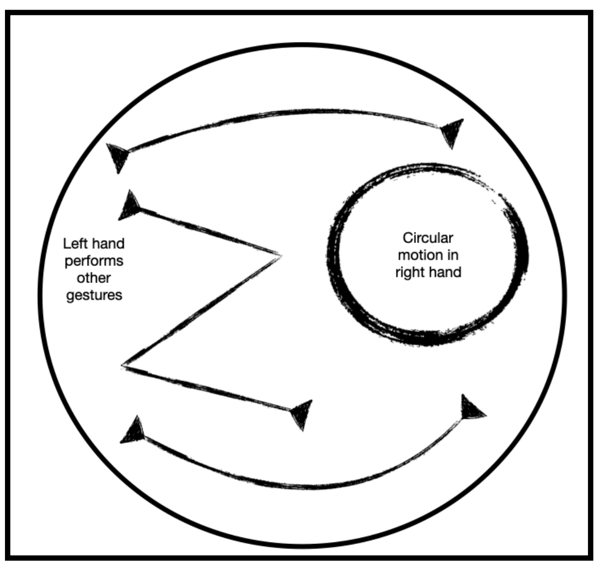

FIGURE 3.21. EXAMPLES OF BRUSH MOTIONS ON DRUMS

A more accurate depiction of the role of both hands looked something like the image below.

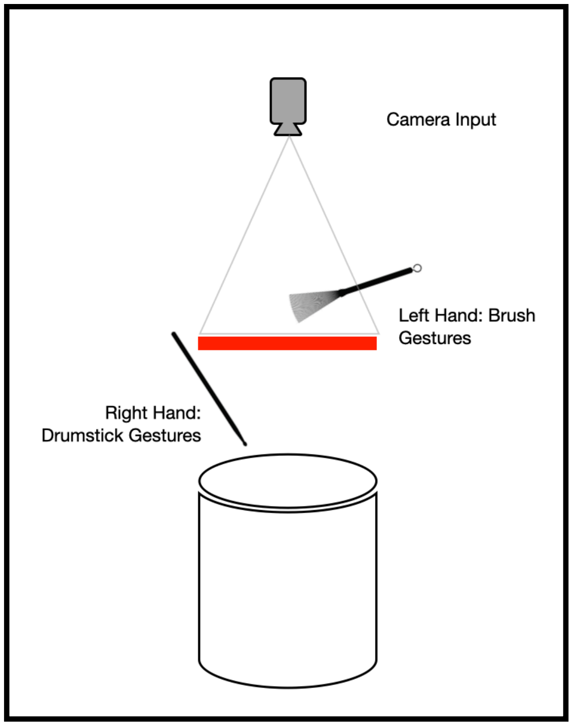

FIGURE 3.22. BOTH GESTURAL MOTIONS, SPLIT BETWEEN TWO HANDS

` I (perhaps obviously) could not use brush and drumstick motion with both hands, nor was it necessary or desirable to use the actual brushes at all. Rather, only the horizontal motions inherent to brush playing were adopted as the primary means of interfacing with the screen. I also did not have to necessarily use two sticks when performing. I started to correlate any motion associated with playing the actual drumhead as the actuator of the initial sound, while the horizontal, brush-based motion was treated as the means to process that which was actuated I started considering the horizontal motion — the means for processing live audio input into the system — as a continuation of the vertical motion. As a result, I started to conceptualize the distinct types of motion used in both planes as being part of a comprehensive macro-gesture, one which was integrated between both the acoustic and the virtual domains. My performance with the *Cybernetic Trap Kit* reflects this approach, and used two primary methods:

1. Playing a phrase on the acoustic drums - usually consisting of short percussive sounds (with the Sunhouse sensors and software connected and routed into the audio processing modules) - that would be recorded, stored into memory. This recording would be then be routed into modular audio processors, the parameters of which were controlled by the data generated by the horizontal motion being detected by the screen-based interface.
2. Playing one drum stroke on the sensory percussion to generate a sustained tone, which is then immediately processing by horizontal motion detected detected by the screen-based interface.

The first of these methods is a non-linear process, as sound is recorded and then accessed again at a later time in the performance to be manipulated. The two motion types occur at separate times in the performance as well. When I play the drums the tracking system is turned off until the recording starts looping and routed through the audio processors. It is only at the stage of this looping that the horizontal motion is ever used to generate tracking data for processing the recording.

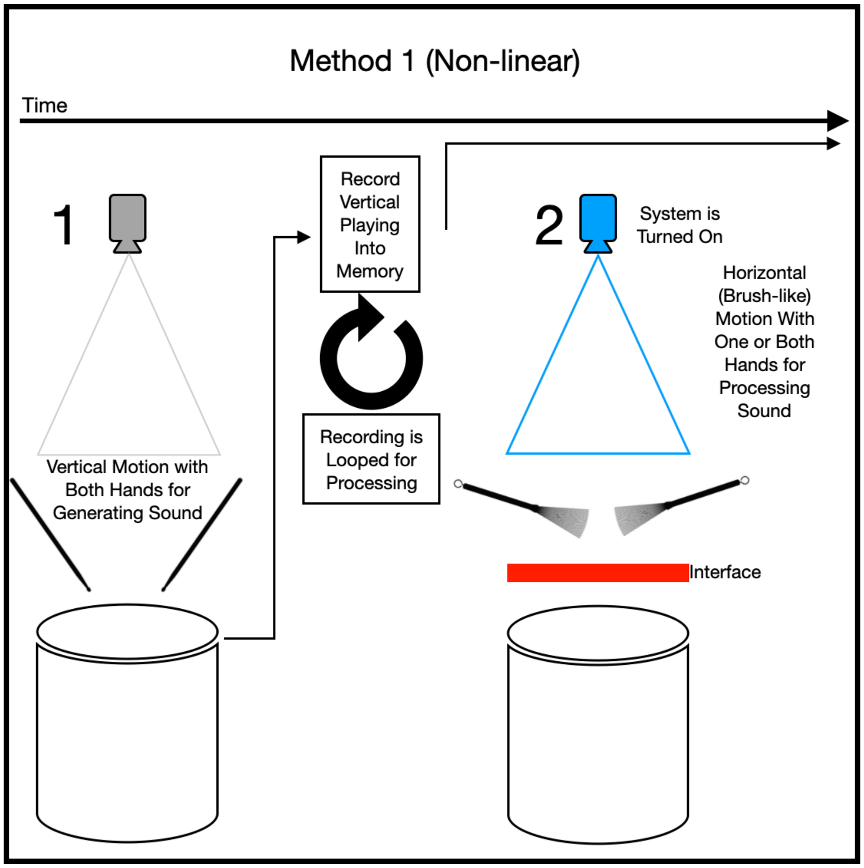

FIGURE 3.23. PLAYING METHOD 1, NON-LINEAR

The second method is the linear option, since the sound that is generated by vertical motion is immediately processed by the horizontal complement. And even though that it is occurring in a linear manner, this is arguably the more complex of the methods. The actuating of sound can occur with respect to some temporal grid while the horizontal motion is nearly always occurring independently of any established tempo. With this in consideration, there are two types of drumset independence occurring with this linear method. One of those is the aforementioned form independence that represents a combination of vertical and horizontal movement necessary for interfacing with the hybrid technological assemblage. Additionally, there is a form of temporal independence, as it relates to that gestural interfacing. One hand can bed playing a motion that can be in-time, and another independent of any established tempo. This temporal independence can be used to elongate one horizontal gestural motion over the course of any number of vertical drumming strokes. This is a practice that I consider as being not so different to the polyrhythmic capabilities of many drummers, yet it is happening between two different material and temporal domains.

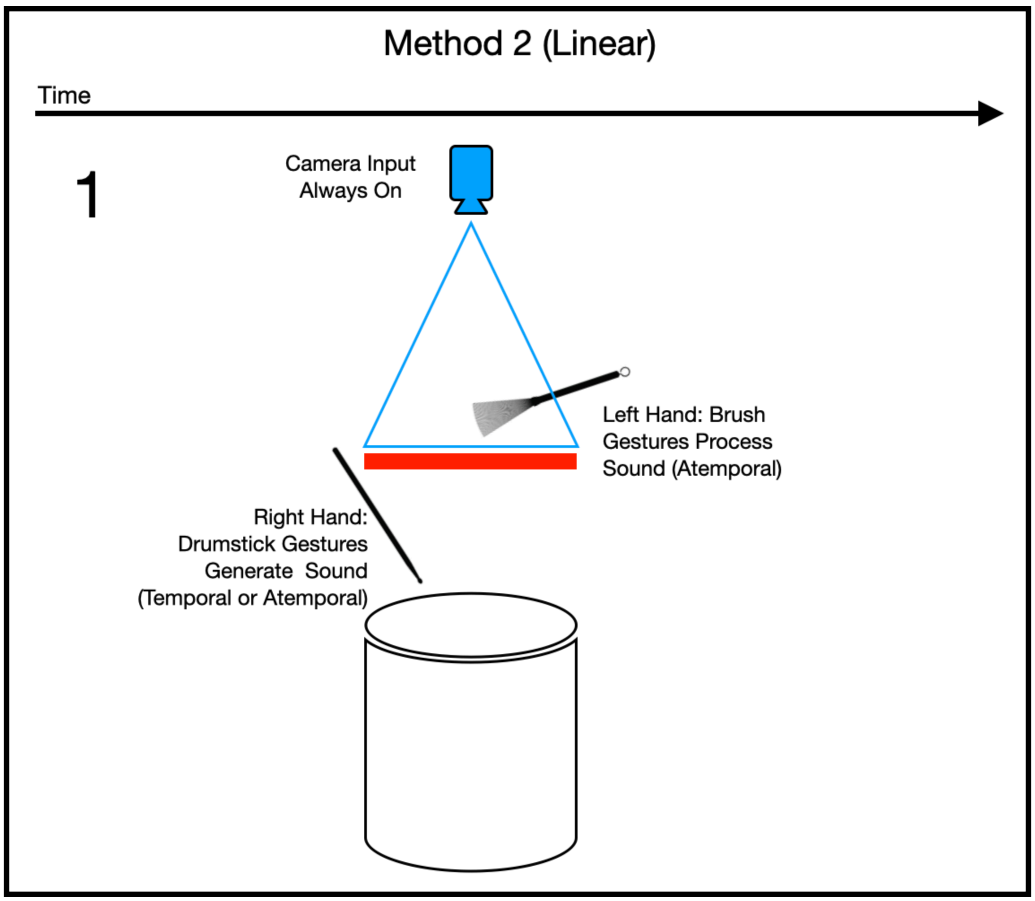

FIGURE 3.24. PLAYING METHOD 2, LINEAR

Through iterative practice and experimentation, I started to realize that there was a third type of motion, and the one that is most overlooked: functional motion between one drum to the next. Recall the paths of motion from Chapter 1:

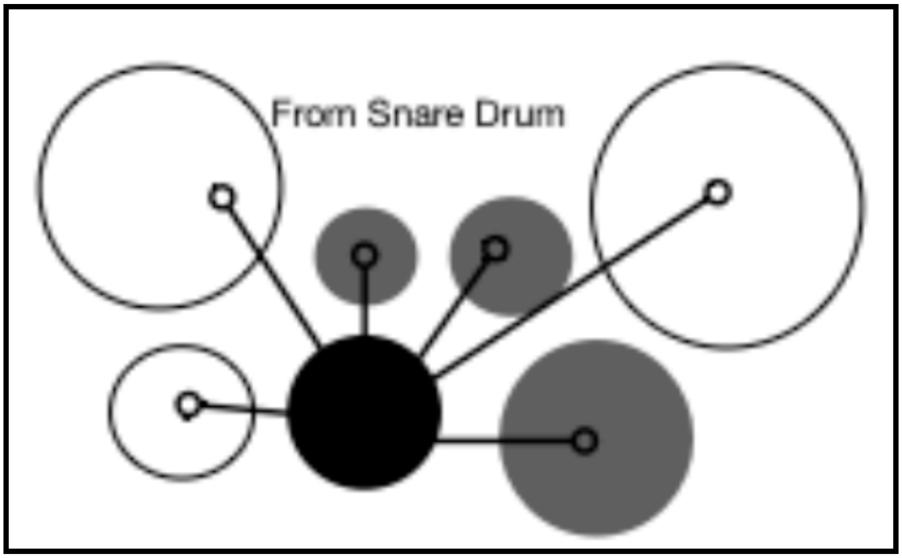

FIGURE 3.25. PATHS OF MOTION, FROM THE SNARE DRUM

This motion from the snare drum - the centerpiece of the CTK interface - goes outwardly in front of the performer. This functional movement from one node (drum) to another can be used as a means to process any generated sound. The motion from one node to the another can additionally be used to generate sounds from virtual instruments. On the acoustic drumset, the motion from one drum to another is merely the means through which a drummer performs a learned gestural vocabulary of sequenced patterns on different instruments.

When using the linear approach, I began to use functional motion from inside the primary processing matrix to indicate the beginning or ending of a phrase, which in both cases, involved triggering one of the virtual instruments controlled by activity inside the rectangular areas around the edges of the interface. I developed a technique where triggering one of the virtual instruments would represent the end of a particular musical phrase or gesture. The sequence of events are depicted in the image below.

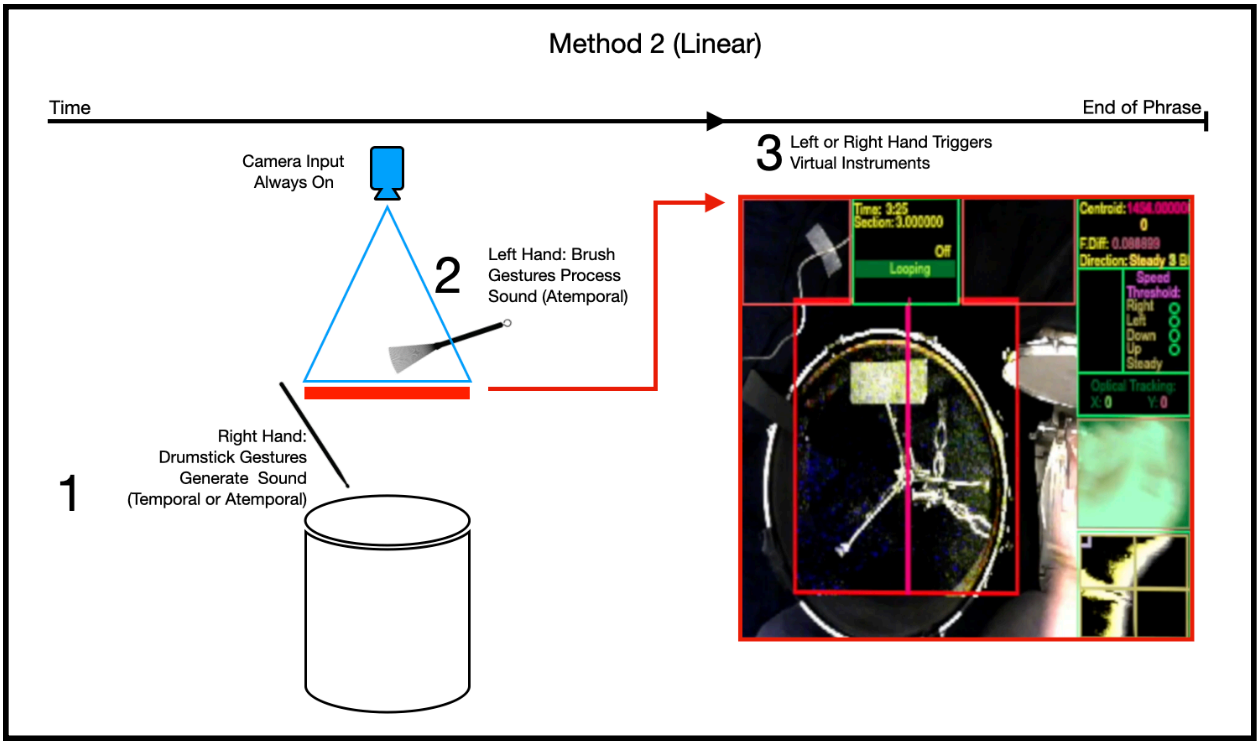

FIGURE 3.26 GESTURAL PHRASE USING LINEAR PLAYING METHOD

The reverse of this sequence of events was another musical gesture that I developed over time. I started conceiving the primary processing matrix as the way my functional motion between playing the sensory percussion and playing a virtual instrument could be tracked. Both the virtual instruments and the sensory percussion audio could be processed by activity within this matrix. After a lengthy experimentation period, I noticed how activity near the edges of the matrix produced more extreme - or perhaps, more demonstrative - sonic results. Pixel location of any motion data in the primary matrix is at is highest and lowest values at this edges, and actually increased as the performer moves down and to the right of the matrix. The video inside these matrices can be represented as a two-dimensional array, where the lowest values are at the top left of the screen, and its highest are located in the bottom right. This presented interesting parameter mapping strategies. For example one edge of the screen could be used to create very short delay times while another side could control the amount of feedback added to it, causing dramatic timbral effects. I used similar parameter mapping strategies throughout the performance, and would move extremely close to the edges of the processing matrix to indicate that a musical phrase would soon comes to an end.

This interaction proved useful for indicating when any activity was being detected in the matrix. And while this technique was not originally planned to be used a from of perimeter sensing, this "edge detecting" proved useful for another task: triggering processes on or off. More specifically, the edge detection features were a practical method for controlling the myriad of audio signals output by the system at any given point in time without actually having to manually turn anything on or off during live performance. One of my chief concerns was having to navigate away from the screen interface during the performance in order to mute or play a particular audio source. This would not only detract from my personal focus on performing but diminish the overall experience for the audience as well. Perhaps this is a subjectivity unique to my personal playing style, or as a result of combining computer music practices with drumset performance, but spending minutes tediously pressing any number of button or moving a cursor around the screen in the middle of a piece is indicative of poor compositional planning. It is certainly an approach that does not center the human during the performance at all times, and more to the point, seems like an unrealistic expectation to place on the drummer. How would anyone be able to perform when they were tasked with constantly managing the flow of audio signals?[132] In a software that includes as many audio signals as the *Cybernetic Trap Kit*, this responsibility needed to either be automated, or ideally, managed by interacting with the screen in real time. If done through interacting with the screen, then the routing of audio signal is subsumed with the performance itself, rather than being an independent task accomplished through an entirely different form of human-computer interaction.

The most effective way of controlling audio signals with the interface was to program the primary processing matrix to function as an on/off switch. I created parameter mappings where a collection of signals would be turned on when I entered the matrix while another collection of signals would be turned off. The inverse also took place: that collection of sounds that was triggered by motion detection were muted when I exited the matrix, while the once-muted group of signals were turned back on. Just this simple mapping created world of possibilities for me as a performer. I created four groups of audio signals, listed below:

1) Main Output: includes all audio from modular processor and recorded audio.

2) Sensory Out: includes any audio only generated from the Sunhouse Sensory Percussion.

3) Virtual Instruments: includes all physically-modeled and virtual synths.

4) Spoken Word: audio files of speech excerpts that were triggered on by the use of Frame Differencing.

[132] It is important to distinguish between the two types of signal management being discussed: the transitioning from one collection of signal routings - previously referred to as a "preset" - and managing the playback of those signals routings in real-time. The first is automated by the score controls, while the second is managed by the drummer during performance, and determined by parameter mapping and interactions with the interface.

All signals comprising the section-to-section routings that are automatically transitioning during the performance are summed into these four groups. I then created four different "master" routing states that the user could select from, each of them having a particular function based on performer interaction:

1) Thru: This option would play audio continuously, no matter what occurs between the human and interface.

2) Off: This option would turn audio off continuously , no matter what occurs between the human and interface.

3) In - Out: Any audio routed into this option would play if the system detected activity and would then be muted once the performer left the matrix.

4) Out - In: The opposite of In - Out. Sounds is played when no activity is detected and turned off once the user enters the matrix.

Combined in different ways, these signal routings and the methods to control can produce a myriad of sonic results. Consider the following routing:

Signal Groups	Thru	Off	In - Out	Out - In
Main			■	
Sensory	■			
Virtual Synth.	■			
Word				■

Table 3.2 Signal Routings, Section One

The table above is the master signal routing used in the first section of the concert. The piece starts with an open solo played on the Sensory Percussion, followed by starting a ninety second recording of a repeating pattern that combines pitched and percussive elements. This pattern is looped for the remainder of the piece, and routed into the modular audio processors. Since the recorded looped is summed into the In - Out signal routing, this audio is only ever heard when activity in detected inside the primary processing matrix. Furthermore, this audio is never heard in its original form, as it is always being routed into the modular processors. The exception to this is when this recording is played at the ending of the open solo. When the piece transitions to signal routing that featured the audio processors, then the record is essential used as raw material to be manipulated through extended gestures that interface with he screen-based cybernetic components of the hybrid instrument.

Using this master signal routing, I can play the Sensory Percussion continuously while cueing virtual instruments by entering the smaller sub-matrices located in the upper and right-most side of the interface. I can play discrete phrases and patterns on the Sensory Percussion while I extend my gestures into the area of the screen that cue the virtual instruments. I interpret the playing of these virtual instruments as a method for generating sustained sounds on this adapted hybrid assemblage - the equivalent of playing the cymbals on an acoustic drumset. Meanwhile, since the “Main” audio components are routed to In - Out, this audio is completely silent unless I physically enter the primary processing matrix. This affords me a myriad of musical choices. First, I have access to a highly processed, electronic timbres that augment the Sensory Percussion sounds. I can also layer these timbres with the sustain provided by the virtual instruments. Additionally, I can use the primary processing matrix to sonify my horizontal functional motion as I transition from playing an acoustic drum to actuating a region of the screen that cues a virtual synth. Perhaps most crucial to the performance is that the combination of the those three elements and their master signal routings affords me the opportunity to create a aspect of electronic or electro-acoustic music performance that is very much needed : the use of silence. After the initial solo and recording with Sunhouse Sensory Percussion, I can use the acoustic drums solely at my discretion, to the point where I never have to play them at if I so choose. The same options are afforded to me for cueing the virtual synths, or entering the main matrix to process the recorded loop. Considering the number of electronic timbres being heard at one time, being able provide the user control to alter the level of sonic density being produced and heard at given point in is a key component to the performance. And perhaps on a fundamental level, the ability to start and stop the generation of sound, is also an essential consideration in constructing any musical instrument. Even if I were to choose to play without any rests at all, programming the features that enable one to to do so is of paramount importance.

A crucial part of the performing with the *Cybernetic Trap Kit* is being able to improvise on a number of levels at once, all controlled by the gestural interactions with the screen-based interface. I not only have to play the instrument of of course, but just like any other performance, demonstrating a vocabulary on the instrument is contextualized by phrasing, managing the trajectories of density over time, and using silence as an effective compositional tool. These routing describes above, and the design of the software, enabled me to be able to approach improvising with their hybrid instrument in a similar way in which I would do so with an acoustic drumset or another performer in the ensemble.

The underlying design of *Cybernetic Trap Kit*, and the performance approaches I have developed with it, reflect my position that, at times, musicians unconsciously adopt the use of a technology that can be interpreted as arbitrary or even trivial, oft doing so in a way that reproduces an outcome that could have been achieved through any number of different methods or technologies. It is rare for me to have personally witnessed a performer or composer comprehensively integrate an emergent computer-mediated technology with an existing musical practice in a manner that creates a hybridized instrument that must be accepted on its own terms. The amount of concerts and conferences I have attended where composers use what they refer to as "cutting edge" technologies to essentially reproduce musical outcomes that could have just as easily been achieved by Tape Music practices can confound and perplex, and often leave me thinking if this particular use of technology was necessary at all to producing the musical result.

Far too often in electro-acoustic practices, the technology involved in the composition and improvisation is assigned a unidimensional, auxiliary, or tangential role in the creative process and their outcomes. If the computer is to be used to augment and re-examine one's relationship to an existing musical practice, then it is my position that the technology needs to not only be fully integrated with the existing acoustic instrument, but the broader hybrid assemblage justifies its use by producing a sonic result that is unique - or at the very least, irrevocably conditional to all its components and the technologies therein. This is to say that the technologist, designer, and musician (which in this case, is the same person) should demonstrate that the application of a given emergent technology is not only justified, but essential to achieving the creative outcomes of the project. If not, then the project, from a technological perspective, is an exercise in vanity. Integrating a technology into a performance in some haphazard manner simply because it can be done is not a justification for doing so. To provide an example, one can wonder why it is necessary for a performer to strap a wearable sensor around their instrument or body and move around to simply to trigger an audio file to play, when a MIDI foot pedal, or any number of other established and less technologically complicated methods of doing so, would have sufficed. One's gestural relationship to an acoustic instrument is being altered, but for what purpose? Clearly articulating the goals for using a particular technology within an existing musical certainly aids in contextualizing the work for others.

This criticism may seem overly harsh, and I may be merely identifying one of the primary differences between thinking of oneself as a composer first and foremost, rather than as a music technologist or technical designer (with which I would primarily identify). To be fair, anyone's effort at integrating technology into a musical practice is on a timeline unique to their own experiences, and that should be respected. With that being acknowledged, if a composer willingly opts to use the computer as a key component in their work - especially if the machine is purportedly conceptualized as a creative agent - then they are to some extent, a music technologist. The way technological assemblages are presented in performance is a measure of one's aptitude within this domain, but more importantly, a musician's actions are indicative of how the audience is supposed to perceive any form of music technology and a performer's relation to it.

The treatment of emergent technologies as being ancillary to musical outcomes reduces their creative possibilities to mere novelties. Used in this way, technologies are portrayed as methods of re-production rather than the means of experimenting with novel creative potentialities. These observations have been made since the early 20th Century, with one example being Lazlow Moholy-Nagy's comments on the duality between production (creation) and re-production in art:

> Since it is primarily production that serves human construction, we must strive to turn the apparatuses (instruments) used so far only for reproductive purposes into ones that can be used for productive purposes as well.[133]

In regards to the advancing technological evolution of the 20th Century, Moholy-Nagy's dichotomy of production and re-production foreshadowed the developing classifications of instruments and media: implements of creative expression expression, on the one hand, and methods of communication, on the other. However, these orientations represent static states that a musician must assume towards technology, and the emergent tools at their disposal are not limited to one particular function. The distinctions Moly-Nagy made demonstrate the poles of the two opposing orientations to technology. As advancements in 21st Century technologies improve and proliferate, the distinction between media and invention is more fluid than static. The dichotomy between creative technologies and media of reproduction has long been inadequate to depict the reality. It is not so much that the distinction exists in the objects themselves, but rather in the way the objects are used that creates this illusion. Musical instruments or reproductive media, in this sense, do not impose a unidimensional technique on the user, but offer a range of creative outcomes or possibilities. Digital Media, at its essence, is a form of data that is itself comprised of other data, which can be manipulated to serve whatever utilitarian or creative end the users desires. It is not just for reproduction; even the reproduced video image or audio recording can be reduced down to quantifiable data, which can them serve a vital function towards achieving a creative end.

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[133] Moholy-Nagy, László. *Production-reproduction*. Studio international, 1975.

Despite this fluidity, we have arrived at a fascinating crossroad in music technology: the tools are at once a potential liberator from these musical confines, yet more often than not, they used to reify the weight of history that reinforces these musical enclosures. Paradoxically, so much of our current electro-acoustic musical produce using contemporary technologies is confined by the accumulated notions of music that are unique to each culture and the civilizations from which they were established. I would assert that the use of emergent technologies of the 21st Century to reproduce 20th Century ideas relating to electroacoustic music traditions is a music-related example of society's tendency to reproduce itself.

My approach to this concert was deeply influenced by the above considerations. The constant need for musicians to transform their musical produce into an object serves many purposes anchored to material reality. Of course the ability to earn income for one's work is the most obvious, but there are others as well: being granted composition commissions, acquiring a position or employment at an institution, earning tenure at a university, or transforming the status of being a renowned composer or academic into a form of social capital, are just some of them the motivating factors involved. All of these results, which yield material outcomes, are contingent on one's ability to produce in great quantities. Where would one find the time to learn how to incorporate a nascent, often complex and wholly unfamiliar technology into an established musical practice when the need to produce is so unrelenting? Furthermore, the music industry can be thought of as a complex web of a reified system of objects, all of which serves a function to commodify the produce of musical labor. Considering the pressures to produce under these material conditions, it is no mystery as to why emergent technologies may be used by musicians to either replicate musical traditions of the past, to reproduce sonic outcomes that previously yielded some form of capital for themselves, or to completely discard their creative potentialities altogether. In changing the technological assemblage to include technologies such as motion tracking, the function of the technology as it relates to the jazz drummer, as a specialist themselves, has been undisputedly, and irrevocably, disrupted. By changing the technological assemblage at a drummer's disposal comes an opportunity to resist the tendency to replicate and reproduce the pre-existing functions of this specialist, and to innovate a new relationship to technology and performance that can exist outside the homogenizing forces that can influence the performing musician.

When practicing with the *Cybernetic Trap Kit*, I thought about the above considerations often. I wanted to demonstrate how digitizing music performance and human gesture functioned simultaneously as media and data, and how both of these two components of reproduction can be used to drive the creation of art in real-time. I did not want the concert to merely portray the software and the resulting user experience as some sort of musical toy that had a single musical function, one which could be produced by some other technological means. By my own terms and positions on these matters, if the performance, the audience and user experiences, as well as the sonic results that came from interacting with the overall hybrid instrument , could be replicated by a far less complex technological assemblage, then the concert would have been deemed as less than a success.

This meant that I had to devise a set of music that did not just simply use the *Cybernetic Trap Kit* in every piece, but had to demonstrate how the software could be assigned a distinct musical function within the same assemblage, across different points of the performance. Furthermore, I wanted to demonstrate that every Video Data Point —

Blob, Bounds, and Centroid Tracking, Speed and Direction Sensing, Frame Differencing, Perimeter Sensing, Optical Tracking — could be used in a performance to accomplished various musical tasks. Even though the software is manifold in its complexity, I also wanted to demonstrated how every one of the Computer Vision technologies included in the systems could have a direct effect on musical outcomes, making them all integral to the performance at one point or another. Despite the presence of so much virtual technology, my objective for the performance was to not situate myself as the administrator of an automated system that was far outside my own control, but to center the human aspect of the performance as its most consequential component. As it relates to the performance, I did not want to be reduced to an extension of the machine, but to be considered the essential element in the mediation between all mechanical and virtual components of this assemblage and the ensuing music that was made. Lastly, I was striving to create a set of music this particular assemblage of music that would be documented, but incredibly difficult to reproduce in perpetuity. More than achieving any particular qualitative sonic outcome, the success of the concert hinged on the criteria above being fulfilled.

Taking into account these considerations, I deem the concert a great success. Every technical component to the performance worked as it was intended - a sizable personal victory in and of itself - but the four sections of the performance adequately demonstrated all of the priorities above. The first section did this by demonstrating that the *Cybernetic Trap Kit* could be subsumed into an existing percussive assemblage, and that the recorded audio could be used as material for real-time processing. The parameter mappings enabled the creation of musical phases with both vertical and horizontal motion between the acoustic drums and cybernetic components with varying levels of density and space, the result of which were fully under my control.

The second section did this by using the primary processing matrix in the *Cybernetic Trap Kit* as a virtual trigger. The audio from the beginning solo was played used again, this time as an input into an audio sequencer that mangled the audio into bits and pieces of audio that, when played back, were rhythmically syncopated but in time with my own drumset playing. When activity detected inside the primary processing matrix the sequenced audio was silenced only to be turned back on when no motion was detected. Since the camera was positioned over the snare drum, every time I motioned to the drum the sequence would stop. This simple yet highly effective mapping made it seem as if there was rhythmic interplay and interaction occurring between the virtual components and my drumming. I could also also randomize every parameter associated with sequencer on a note by note basis, including the pitches, the amount of rests, feedback amount, duration of each note partial, by entering into one of the smaller matrices located on the right most part of the screen. The Sensory Percussion was programmed to trigger pitches determined by the velocity of each drum stroke on the snare drum and performed over a triplet-based pattern played between a combination of the bass drum and the sounds mapped to its rim. I could still play with the sequencer when I stopped entering the the primary processing matrix. Since the rate of the sequencer determined the tempo of the triplet pattern, I would routinely approach this section of the performance by alternating between these two groupings of sounds, with the triplet pattern being the one constant.

Approaches	Triplet Pattern	Sequencer	Pitches	Sustained Tones
Grouping 1 Hand Inside Matrix				
Grouping 2 Hand Outside Matrix				

Table 3.3. Sound and Gestural Groupings, Section Two

The predetermined pitch groups programmed into the Sensory Percussion were assigned to an auxiliary drum next to the snare and played by my left hand. Essentially, which grouping of sound is accessed at any given point in the performance is determined by the placement of my left hand.

The third section was the truest representation of this newly developed approach to drumset independence. It was intended to be based around the idea of playing electronic pseudo-Drum N' Bass grooves along with a looped sequence. There were three main sonic components to this thew section:

1. A sound bank, known as a poly-buffer in Max/Msp~, that could store and play up to 144 audio files. In this particular section only six audio files were used, all which were patterns performed on a Buchla 200e, playing eighth notes at the tempo of 80 beats per minute. Each file could be selected through any number of methods - either by specific keyboard, by going into a region of the screen-based matrix, amongst other actions - but I chose to trigger the selection of a new sample by playing one stroke on the sensory drum that was otherwise assigned

no sound or other function. Playing this drum signified the transition to another groove on the drums as well.

2. The primary processing matrix. Any motion inside the matrix processes audio from the sound bank. Just like in previous section, the signal from the sound bank is routed to the modular audio processors, the parameters of which are controlled by motion data. The processed and original audio from the sound bank are played continuously.

3. A selection of the drums with Sunhouse Sensory Percussion attached to them. The fourth drum was not assigned any sounds, since it was used to trigger the file selection feature in the sound bank. The was snare drum was not assigned any sounds either, as the motion inside the primary processing matrix hovered above it. These sounds assigned to the drums did not change through the performance of the third section. My approach with to use mostly eighth and sixteenth note vocabulary to give a double time feel to accompany each sound file.

My left hand and the bass drum would play these patterns in tempo with the audio files triggered by the sound bank, while my right hand would enter and exit the primary processing matrix. The motion within the processing matrix would be independent of the constraints of the tempo that the rest of my body with which my body would be synced. This caused the same kind of dual independence described above: mediating between acoustic and virtual domains while using the combination of synchronous and asynchronous motion within the same musical phrases.

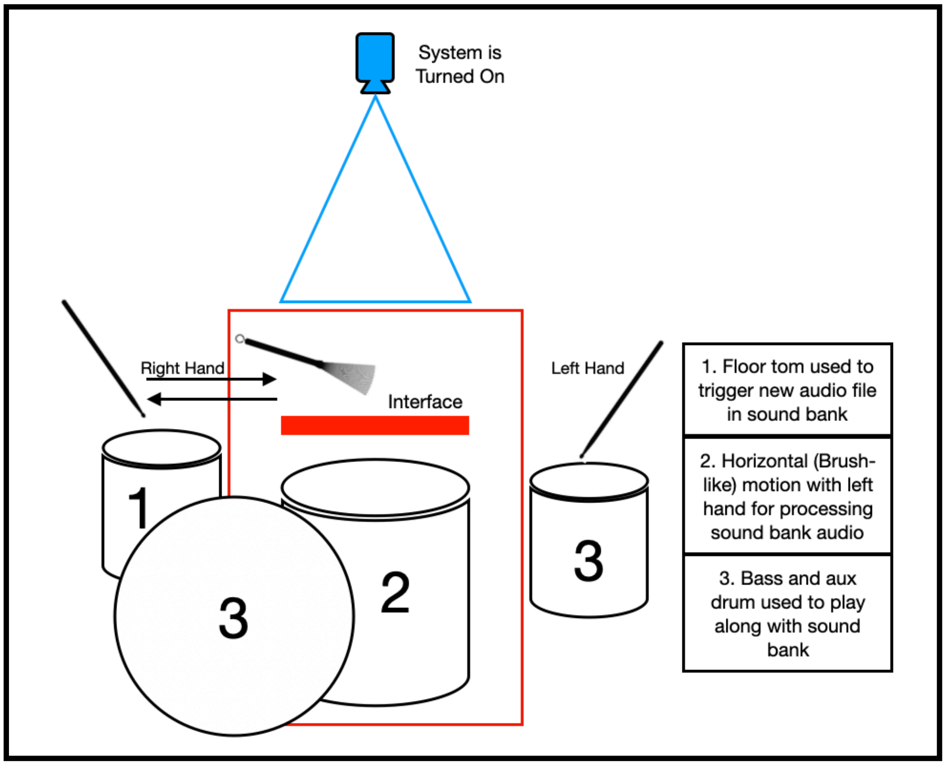

FIGURE 3.27. HYBRID DRUMSET INDEPENDENCE, SECTION 3

The fourth section for the performance took a similar approach with drumset independence to that of the third, however there are some significant differences. One of the most significant of these differences were the motion tracking technologies used within the primary processing matrix. Activity was not measured for centroid sizes, their boundaries and how they changed over time, but in terms of direction and speed. The motion inside the matrix did not process my own performance or any other audio, but was used to control the selection and playback of five audio files stored in four different sound banks. There were five different directions that could be tracked: left, right, up, down, and no direction - or rather put, a steady state, which was also measured in seconds. Speed per direction, that is, the speed at which motion travels in a particular direction, was also measured.

There were forty different files organized by their timbral similarity: twenty to be cued based on direction detection and another twenty played back based on directional speed. Meaning, that there were twenty audio files in total organized in groups of five, with one being selected each time the software recognized a change in directional motion. If directional speed exceeded a user-defined threshold then a sound file was randomly selected out of a bank of five different files as well. The faster I moved, the denser the sound, as this would cause a layering of sound files to be played based on both directional motion and speed detection. This meant that I had to play the snare and use motion with the matrix to control a myriad of sound files at the same time.

To enable the user to have more control over the playback off all of these audio files, the sub-matrices at the top and right hand side of the interface were used to turn the playback on and off. This way I could regulate the sonic density to some degree. Activity into these spaces would not turn the motion tracking capabilities off, but just prevented the audio from being heard.

I used the fourth section of the performance to also demonstrate an entirely virtual form of drumset independence. I would use the optical tracking feature located at the bottom right-hand side of the interface to dynamically mix the balance of audio files together. The optical tracking section is split into four equally-sized panels. The position of the tracking point in relation to those four panels determines the collective balance of the audio files. The balance of sounds would immediately decrease to silence whenever I left the optical tracking section, and would automatically play once I enter this region again.

With that added element into consideration, there were essentially three primary sonic elements that I could control in real-time behind the *Cybernetic Trap Kit* during the fourth section:

1) The playback of sound files related to directional motion and speed.
2) The balance of four audio files, continuously controlled by activity in the optical tracking section in real-time.
3) The playing of Sunhouse Sensory Percussion on all four drums.

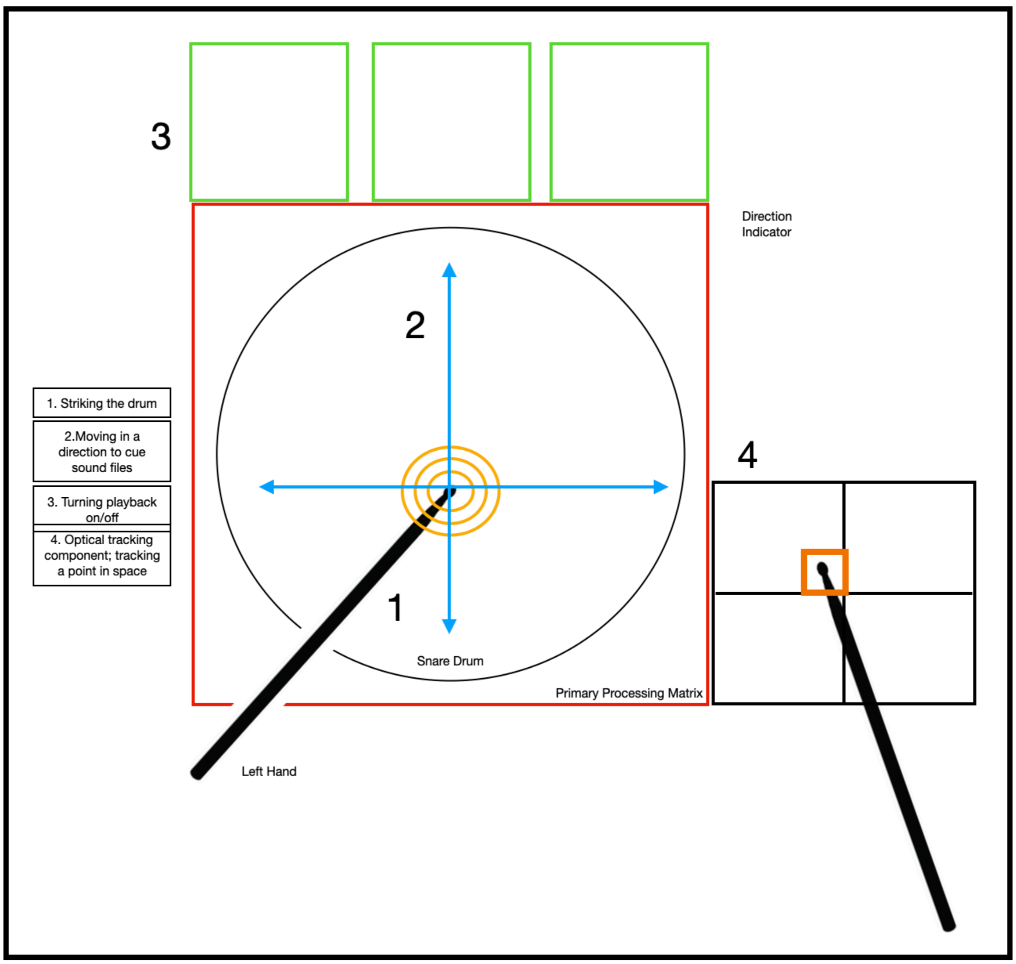

FIGURE 3.28. HYBRID DRUMSET INDEPENDENCE, SECTION 4

The same opportunities for a hybrid approach to drumset independence were present in section four as there were in the first one. I played the drums first to generate some sort of sustained tones, then would transition to the interacting with the virtual elements controlled by the optical tracking and direction sensing technologies. I'd turn off the audio playback of the directional and speed-based tracking features by activating the sub-matrices in there top and right hand sides of the screen. These controlled enabled a variety of variations to this approach. I could simply turn the directional and speed-based audio off, enabling me to simply playing there sensory percussion without engaging in any other sonic element. I could also turn the directional and speed-based audio on and only use my motion with the primary processing matrix to generate sound. I could simply use the optical tracing feature for the means of sonic generation, or combine both virtual interaction methods to accomplish the purposes. I could also combined both virtual interactions methods with playing only the bass drum. The combinations of elements and the gestural vocabulary involved were numerous.

Approach	Snare Drum	Bass Drum	Direction	Speed	Opt. Track
Variation 1	■	■	■	■	■
Variation 2	■	■			
Variation 3	■	■	■		
Variation 5	■	■		■	■
Variation 6		■	■	■	
Variation 7		■			■
Variation 8			■	■	
Variation 9	■				■
Variation 10					■

Table 3.3. Playing Approach Variations, Section Four

There was on last element added to this assemblage: the addition of another musician. I am pleased with addition of another musician for one vital reason. While it was not essential for ensuring that the concert would be a success based on the terms described above, it was important to me to demonstrate that the *Cybernetic Trap Kit* is an instrument capable of interacting with other musicians in real-time. Jazz and other improvised music is a collaborative, social activity. One could even say that a improvising ensemble is it own social assemblage, with each cultivating its own unique ways of navigating this endless negotiation between the individual and the collective, and having the malleability to act upon it are some of the most difficult skills for a jazz musician to acquire. it was important to me to demonstrate that the *Cybernetic Trap Kit* was not a novelty, or some toy-like implement that could only be used in solo context. This would make it a niche instrument that most jazz drummers would hesitate to use in any group context. Adding another performing musicians into the social space of improvisation demonstrated that the technological assemblage that comprise the *Cybernetic Trap Kit* could be used in the musical contexts in which jazz drummers would be most comfortable and accustomed to playing. In fact, the *Cybernetic Trap Kit* was born out of these traditions, developed with these musical situations in mind, and was certainly not intended to exist outside the contexts to which drummers would normally find themselves.

It is for all of these above reasons that I deem the performance with the *Cybernetic Trap Kit* a success. One of the components I am most satisfied with is the fact that the performance seamlessly transitioned from one section to the next, which was no small feat to accomplish. Each section situated the performer so that they would relate to the technological assemblage at their disposal in a comparatively unique manner. Lastly, I demonstrated that the *Cybernetic Trap Kit* was intended to be an extension of these rich history of jazz drums performance and improvisation in both solo and group improvisation settings.

Performance Case Studies

Before my own performance with the *Cybernetic Trap Kit*, the software was tested by some of the most renowned jazz drummers in Southern California. While these experiments did not reach the level of sophistication or complexity demonstrated in my own performance, they had an indelible influence on the future design of the software. Furthermore, the experiences they shard with me regarding their own person history with drumming electronics provided valuable insights into the resistance many drummers feel towards incorporating these technologies into their own musical practice. Their immediate feedback of the *Cybernetic TrapKit* and learning about their performance histories were invaluable in determining the next steps in the design of the software and the presentation of my own performance.

Experiment Format 1: Jason Harnell, Mark Ferber, and Rodolfo Zuniga

Jason Harnell, Mark Ferber, and Rodolfo Zuniga were some of the first drummers to experiment with the *Cybernetic Trap Kit*. A Los Angeles based jazz drummer, educator, composer and bandleader, Harnell has collaborated with some of the most renowned names in jazz over the past thirty years, including Dave Douglas, Maynard Ferguson, Larry Goldings, Rick Margitza, Ben Monder, Alan Pasqua, and Mark Turner. Mark Ferber has played with a wide range of musicians, including Marc Copeland, Ralph Alessi, David Ake, Jon Gordon, Jonatha Kreisberg, Ari Ambrose, and Will Vinson, among many others. Rodolfo

Zuniga is the Assistant Professor of Jazz Studies at California State University Fullerton, and has collaborated with many prominent jazz figures, including Martin Bejerano, Camila Meza, John Hart, Michael Dease, Rotem Sivan, Melissa Aldana, and Andy Laverne.

All of their recording sessions with the *Cybernetic Trap Kit* were similar to the first section of my own performance, although without some of the more complex signal routings.

With the exception of being told how the interface worked, they were given very little instruction as to how to interact with the screen-based interface. Unlike my own performance, the drummers were not responsible for controlling any of the software's larger, more technically involved system settings. That is not to say that the organization of time and generation of sound was completely free of any temporal constraints at all. Musical form was decided by the transitions between signal routings that were established prior to the beginning of the recording. Similar to how I structured my own performance, the sections of the form were thought of as a particular signal routing, each of them processing the live or recorded sound through different modular audio devices. While these signal routings were fixed (yet, easily changed based on virtual patching interface), the interaction model between the human and computer within these sections was based on the performer discovering these emergent gestural-to-sound (and visual) relationships through improvisation and gestural experimentation. Each drummer was given a distinct set of signal routings to explore. None of the drummers observed any of their colleagues playing with the software live, nor did they have access to any prior recordings.

Few constraints were placed on their approaches to this session, yet each was intentional. Some of those constraints that were placed on them were the fixed nature of these signal routings, and having a predetermined amount of time to improvise with each of them before an automated score control system transitioned into the next section. An additional, pivotal constraint was placed on the drummers: instead of using an acoustic drum set - their obvious instrument of choice with which they had a personal sonic and gestural relationship - they were asked to use the Sunhouse Sensory Percussion in tandem with the *Cybernetic Trap Kit*. This was to introduce them to an interesting technology and a drumming experience to which he was completely unfamiliar, but also to guide the recording session into an experimental space before the *Cybernetic Trap Kit* was even introduced. This decision also generated a solely digital sound that they would not be accustomed to playing with, necessitating further gestural adaptation and experimentation. I figured that if the drummers were already in a space that was conducive for experimentation then they would be more receptive of a virtual technology that seems initially seems wholly unrelated to their gestural relationship to the acoustic drumset.

Harnell, Zuniga, and Ferber were all were asked to first perform an open-ended solo with only the Sunhouse Sensory Percussion, after which they would turn on the interface and control system of the *Cybernetic Trap Kit* by pressing on a MIDI foot pedal that simultaneously initiated the software's processing capabilities and the automated score controls. At that point in the recording, they were tasked with navigating the screen-based interface below:

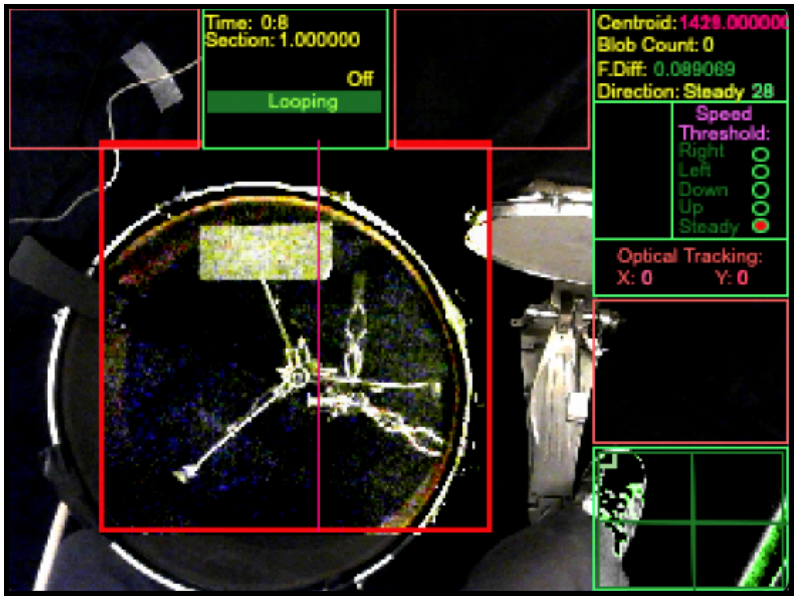

FIGURE 3.29. USER INTERFACE FOR EXPERIMENT FORMAT 1

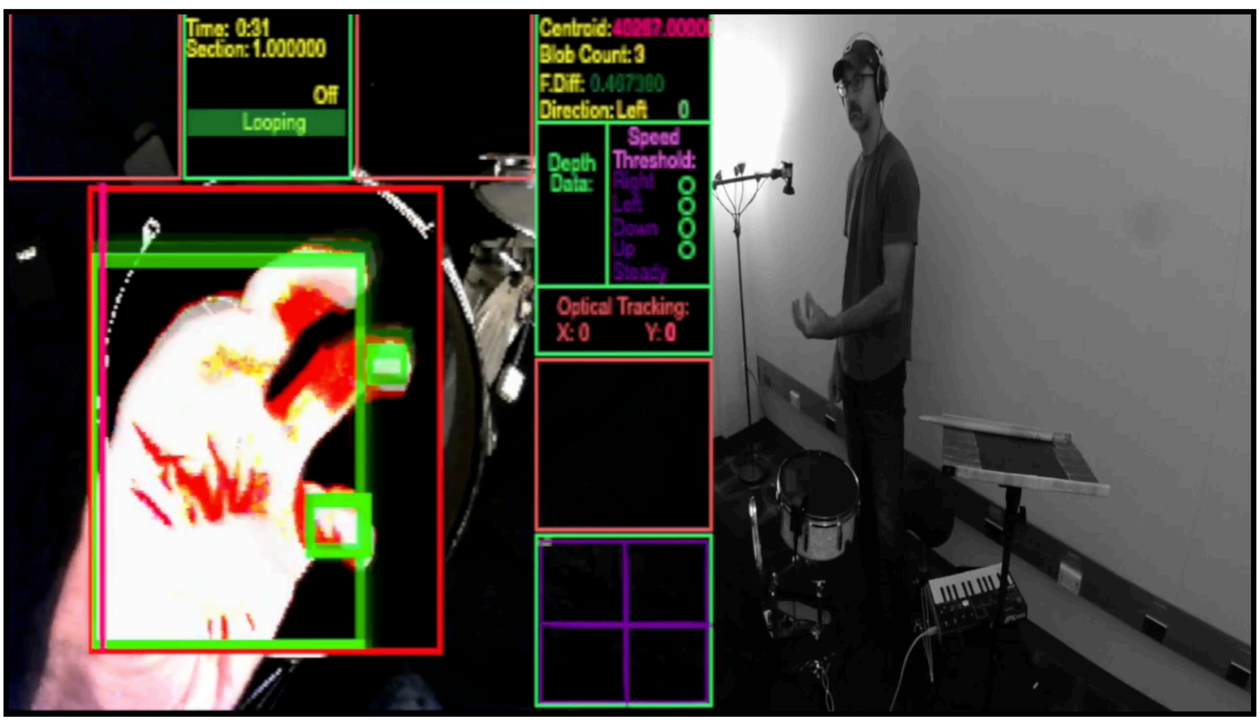

FIGURE 3.30. SCREENSHOT OF EXPERIMENT FORMAT 1, FEATURING MARK FERBER

The solo played on Sensory Percussion was recorded into a buffer which could be looped during the ensuing sections of the recording and processed using the interface as the primary control source. The drummers could also generate sounds in real time by triggering virtual instruments programmed into the system. Alternatively, they could also simply play the Sunhouse Sensory Percussion, and that sounds would be processed by the audio devices. The recording concluded with them turning the *Cybernetic Trap Kit* components of the system off once the score control had executed its instructions, and playing a brief solo on the Sensory percussion.

As the image above demonstrates, the material dimensions of the drum kit were reduced from the standardized drum set to a single snare drum and bass drum. All toms-toms, cymbals, and any other contraptions were removed. The trap kit was now a hybrid cybernetic-physical instrument that only produced electronic sounds - a far cry from the standardized drum set Harnell was accustomed to playing for over thirty years as a professional jazz drummer. Yet, as foreign as this was anticipated to have seemed to Harnell, he shared a different impression when asked about his experiences interacting with the system after the session:

> Oh man, yeah…absolutely. This is so easy to navigate and figure out when you're playing [with] it. The only challenging part about it was that I wanted to hear all the sounds in all their glory, 'cause it sounds so different than my usual [acoustic drum] set up…but I was, I also wanted to hear your direction…for the process…I had to take one earphone off slightly the first time through [the recording]. There's an element of play too that I love. Play is a motto for me and this experience is incredible…

Zuniga and Ferber echoed these remarks in their own words, with Zuniga stating that virtualizing the drumset in a way that still fostered human-centered performance created an immersive environment, necessitating a renewed focus on gesture and motion.[134] Ferber made similar statements while also suggesting that there are other musical applications for this software, namely, designing it in a way that would encourage experimentation with instruments other than the drums. He also felt like he had to "think differently the virtual elements and the absence of cymbals, but in a way that stirred curiosity and experimentation.[135]

Harnell went on to juxtapose his experienced with the *Cybernetic Trap Kit* against his other experiences incorporating technology into his acoustic drum set up. He recalled his sordid past with electronics, and how the *Cybernetic Trap Kit* is just two components yet did not make him feel limited.

> Yeah, for me personally, I love the directness of the drumset. It's kind of like the acoustic piano in that way; you simply walk up to it and start playing. But, I am a child of the 80's! And that's when the Simmons [electronic] drum evolution happened, that was *huge*…[but] the sounds were awful, and I felt very limited in what I could do with them. It was a terrible experience, I mean, I couldn't play the way I wanted to. And without the interface doing exactly what I wanted to do, you're looking at a hexagon that feels terrible to play, there's just nothing there.

Harnell transitioned from his critique of the Simmons electronic drums to describe the terrible feeling of playing on the Roland SPD-30 and the Alesis electronic drums:

> So, I had two of those and did a lot of sessions and they feel *terrible*, and the sensitivity sucks. They're just hard rubber, not even a soft, pleasurable feel. They just don't feel good. I ultimately gave up on drum electronics when Alesis came out with what was essentially this interface, basically this drum module with all these different drum sounds. I bought that and learned how to use it with my acoustic kit and the SPD-30, and I realized that, you know, I'm just going to stick to acoustic drums from there on out. I was disillusioned with the whole thing, especially the triggering element.

The tactile, material relationship drummers have to their instruments is of the utmost importance. This is made more interesting by the fact that the majority of drum set players do not actually touch the drums, but use some sort of implement (sticks, brushes, mallets). If this tactile relationship is lost when interfacing with the material percussive

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[134] Zuniga, 2023

[135] Ferber, 2023

object, then the desire to discover the features that any contemporary technology provides dissipates. Having to account for the constraint of limited sensitivity is too much of a sacrifice. It is also important to note that all three of these drummers involved in this initial experiments stated that they had no interest in playing an electronic drumset that was a cheap simulacrum of the acoustic original.Harnell went on to discuss what he required from interacting with electronic or digital drum set, stating that, from the user standpoint, he prefers accessibility, versatility, and intuitiveness over trying to recreate the ergonomic and tactile sensation of playing the acoustic drums into an electronic space:

> I feel like what you've done here is to combine the best of two worlds: the acoustic and the electronic. One does not negate the other here. Meaning, there are conventional things you can do with this set up and then you can do, I mean…incredibly vibrant, new territory to explore. That's how I would describe it, in terms of what it lets me do… not only in what I play but how I would play it… the more I was able to use it as I'm assuming you intended, which is as a compositional tool, and not something to just play around with to see how cool it is to move your hand around and hear all these different sounds; to use it to actually shape the sounds over time and then combine that motion in the red box with moving into the other boxes around the screen in an intentional way.

Harnell's juxtaposing his experiences with the Simmons drums to that of the CTK is illuminating, and potentially explains why he described the first encounter as laborious, tedious, and ultimately defeating, while the other was thought to be fun, accessible, and lending itself to experimentation. The interface of the *Cybernetic Trap Kit* is meant to resemble the drum kit, bringing an element of material familiarity into the digital space. However - and perhaps most crucially - the design does not shoehorn digital sounds onto materially manipulated plastic objects in order to access these seemingly new sounds or virtual instruments. Since the Simmons drums were still a material representation of the drumset interface, there is an expectation for their tactile response to be somewhat uniform with the gestural familiarity drummers accrue over years playing the acoustic drums. When the material familiarity of the drum were taken away and the digital sounds were (admittedly, subjectively) “awful”, then interacting with a material facsimile of the acoustic instrument left the drummer wanting for something more responsive and synchronous to their learned rhythmic experiences and gestural reflexes. Inevitably, and understandably so, this led to a resistance in experimenting with electronics in drumming. If the experience feels gesturally limiting and seems musically compromising, then the whole endeavor is viewed as subtractive to one’s creative potential.

This is not meant to overly critique Simmons Drums, which were a tool that reflected the technology contemporaneous of the 1980’s, and a musical tool which, of course, could be mass-produced by a prominent manufacturer at that time. However, all these products — the Simmons drums, Alesis drums, the Roland SPD-30, and even their state-of-the-art V-Drums — offer drummers a somewhat rudimentary electronic sound palette while attempting to recreate the physical resistance they experienced from the acoustic drumset. Since these drummers already have a tool that easily facilitates this resistance in the form of the acoustic drums, one can wonder what it really means to use these electronic instruments to accomplish these same purposes. The creative purpose of these products can allude the musicians to whom they are being marketed.

Noting the differences in design and intention with these products and the *Cybernetic Trap Kit* are insightful, if for no other reason than to explain why these drummers had radically different experiences with the two instruments. In the case of the *Cybernetic Trap Kit*, material elements are taken away from the standardized assemblage of the material drum set, as opposed to manipulating the spatial dimensions of these physical objects with which drummers grow so familiar. The drummer must accept the *Cybernetic Trap Kit* on its own terms, and embrace the creative possibilities it provides them. The immediate constraint is obvious, which is the absence of the standardized drum set assemblage in its material form. But it is through levied constraints that the system's features are revealed in an emergent manner. Virtualizing so much of the standardized drumset was the catalyst for curiosity and experimentation. Oddly enough, removing nearly all the drums away from the technological assemblage entirely makes all the difference in the drummers left feeling wanting for familiarity or eager to explore the potential in developing an augmented gestural and sonic vocabulary.

Embracing the obvious constraints leads to an open engagement with the systemic design of the software, which precipitates an exploration into the ways with which the drummer can leverage these discovered features into a new gestural and sonic vocabulary for musical expression, one which was inspired by the materiality of the drum set and mediated through virtual technologies. Within this space, the drummer discovers the flexible ways in which they can use the *Cybernetic Trap Kit* to their own musical ends, which includes live sound processing, generating new sounds with virtual instruments, or using their own gestural data as a control signal to manipulate digital visual signals. In lieu of resignation, there is a renewed mediation with technology, one which does not exclusively preclude the use of existing vocabularies or performance models, but augments them into exploring the outer musical limits and possibilities within a configured virtual assemblage.

Experiment Format 2: Tina Raymond

It would be remiss of me if I did not include the documentation of a partially failed experiment that was conducted around the same time as the one mentioned above. I deem this an artistic failure because it resulted in less-than-stellar musical outcomes, but even this process proved useful in determining the long-term creative efficacy of the *Cybernetic Trap Kit*. I view this software as being able to be applied in various creative environments, certainly more than the ways it has been presented in this dissertation work. For the purposes of this dissertation, the software has been designed and presented in a way that resembles a virtual drumset interface, but in a broader sense, I conceptualize it as a utility for network building and data visualization. When conceptualized in this manner, the software becomes far more powerful and versatile than when just presented as an interface for drummers. The motion tracking capabilities of the software exist independently of any particular user input; whether it be a drumstick, a hand, a dancer, live input from a webcam, video recording or still image, the technology will work the same. The *Cybernetic Trap Kit*, therefore, is one instantiation of this software, and certainly not the only way to appropriate it to realize some creative purpose. I view the software as a data accumulator that can store motion tracking info in a sequence, and subsequently send the results of its analysis to other software or hardware systems, thereby creating audio-visual networks of varying complexity and scale. This process can happen asynchronously or in real-time.

To provide a more concrete example, a video can serve as the input of the system and motion tracking technologies can follow the moving image, just as it would my hand or a live performer's actions. This data can then be routed to a visual programming environment such as Adobe AfterEffects, Resolume Avenue, or Touch Designer, to drive the real-time manipulation or processing of other images. Another example would be to use a projected piece of video art as the input into the system, and to subsequently use the motion data to control the spatialization of an audio design schematic embedded in a hybrid software-hardware audio system, such as Q-Sys or Crestron. The varying degrees of networked complexity are only limited by one's imagination and technological resources.

My experiment with Tina Raymond, a renowned jazz drummer in Southern California and Chair of the Jazz Studies Department at California State University Northridge, was based around her improvising to a five minute video about life in America during the post-Great Depression 1940's.[136] To shorten its duration, I edited the video and changed the speed of its playback at certain timepoints. Raymond was given little direction on how to construct her improvisation (an error on my part, in retrospect), only to vary the speed at which she played based on perception of the how fast time was passing in the video. The video was essentially her real-time score, while the software analyzed the video and stored its motion data onto a .txt file that could then be used to process the drum audio asynchronously at a later time. Essentially, the motion data derived from the video would drive the processing of Raymond's drum solo.

[136] The video was a black and white government video from the FDR presidency, focused on building the infrastructure of the Mid-West post Great Depression. it was originally over fifty-five minutes long, edited down to five minutes and thirty seconds.

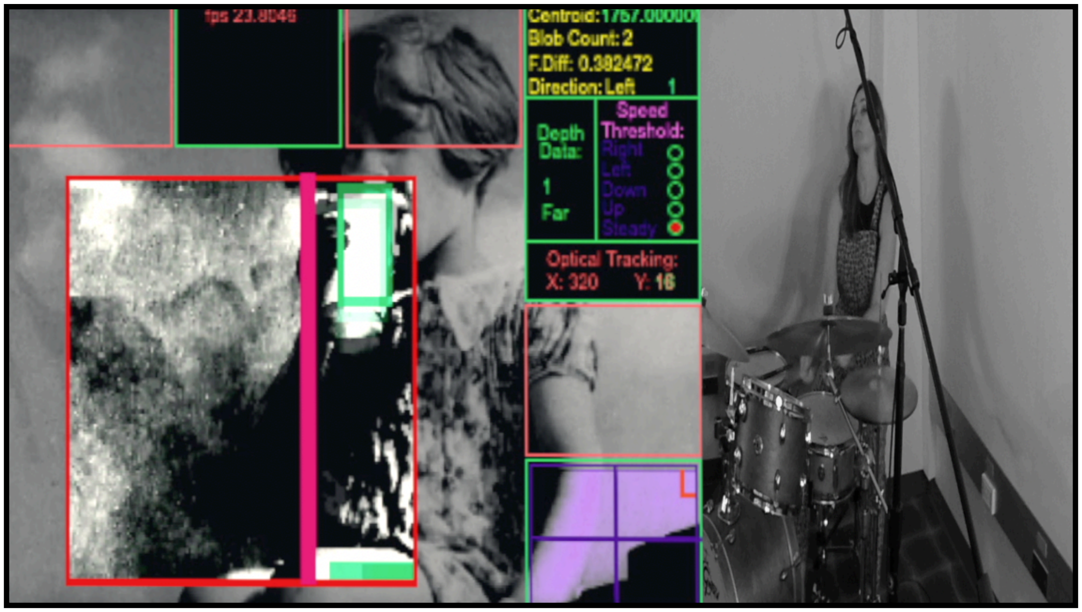

FIGURE 3.31. SCREENSHOT OF EXPERIMENT FORMAT 2, FEATURING TINA RAYMOND

Perhaps calling the results a failure is too critical, but I view my selection of a video that had far too much motion in it to generate data that could be focused into processing Raymond's solo a misstep. In retrospect, I should have given Raymond far more direction than I initially provided. Her performance was excellent and certainly not the reason that the results were less than what I expected. Ultimately, the primary reason for these lackluster results had more to do with the decision to process Raymond's sound asynchronously rather than let her hear the processed sounds in real-time. If she could have heard her processed sound in real-time, then this audible feedback would have functioned as her accompaniment, which is a manner of improvisation to which she is very accustomed.

While this experiment has been labeled at "Format 2," it was actually the first session scheduled to take place. Due to her demanding schedule, these tests had to happen around three weeks before any other session occurred. The software was not quite completed to the degree to which it would be for all the other sessions that took place during experiment Format One, which is why the decision was made to process Raymond's sound in an asynchronous manner.

Regardless of the outcome, the experience will influence my subsequent creative decisions in a number of ways. It is helpful to be reminded that any media that is digitized can be quantified. If media can be quantified into discreet measurements then it becomes a form of data to be used to drive other processes. As an artist myself, I do not typically conceive of my creative work as a form of data, but whether art is completely analog, material, or digitized or fully virtual, it can be considered a type of artifact to be used to influence new iterations of the same produce or even completely unrelated forms of creative activity. In this case, the temporal qualities in digital visual art can be analyzed, quantified and used to drive the sonic processed of a musical performance. The opposite is also true, where the gestures involved in musical activity can be analyzed and used to affect the processed of either sonic or visual material. Moreover, once media becomes digitized it can be used to create networks of varying complexity for the purpose of establishing new, multimodal domains for experimenting with gesture and interpreting the artistic results.

In a world where nearly anything digitized can become networked with another digital technology, then parameter mapping is the key to imbuing meaning to creative mediations within these interdependent systems. The aesthetic choices creative technologist's make matter just as much as the ability to create these networks. In fact, the networks are ancillary to the way they are presented to the artists, and by extension, the audience. As it relates to the *Cybernetic Trap Kit*, what does have a direct effect on the software's efficacy is choosing source material (an input) that will be able to generate data that is easily mapped to sound or visual processing parameters, and the ability to translate that system design to an audience. This was a valuable lesson to have reinforced, and as intuitive as it may seem, it is easy to lose sight of how these complex networks may be translated to those not involved in their creation.

CHAPTER 4: REFLECTIONS

The standardized drumset is a quintessential instrument of the burgeoning industrial capitalism in the mid-19th and early 20th-centuries. A combination of powered machinery that made instrument parts interchangeable, an implementation of railways and updated, modernized transportation systems for the exchange of goods, as well as the changes in labor relations that were experienced by workers in a free market economy, were all necessary for the drumset's nascent standardization to come into existence and spread through the nation, and eventually to the rest of the world. What were once unique contraptions devised in the home - a produce which emanated from workers' administering of their own time, procurement of personal resources, and individual ingenuity - became an instrument made uniform by an expanding economy that placed an emphasis on the increased division and specialization in labor, and above all, a greater efficiency in the management of a work force's labor power. This efficiency resulted in a rapid increase in the production of goods, both in terms of speed and quantity. Henceforth, the household was no longer the site of production but the grounds for consumption of that produce which was developed elsewhere - where members of said household went to have their specialized skillset and most importantly, their time laboring, made more efficient.

The social and political effects of these changes - both beneficial and problematic - can be read at-length elsewhere. What is immediately relevant here is that the drumset was a result of this efficiency, and reflective of this very tenet which is exalted as an axiomatic component to the modern-day American economy. Even the implementation of the drumset into Vaudeville music acts was an act of efficiency, not one of necessity. Why pay three percussionists to play the drums, cymbals and other pitched instruments when management could pay one musician to perform all three tasks while offloading the cost of the drumset, as well as transporting the instrument from place to place, to the laborer himself?

This tenet of efficiency continues on to this day in the production of the standardized drumset assemblage. However, currently this efficiency takes on the form of virtual drum sets and beat-making capabilities and features embedded in music production software, making the labor of producing replicable drum patterns as cheap as consumer technology can provide. No need for a recording studio, purchasing a physical instrument, hiring a musician, or negotiating a wage for their services when the simulacra will suffice for an audience who is, by and large, none the wiser to these changes involved in this particular process of musical production. That this degrades the essential skill involved in playing the drumset henceforth is not the primary aim of course, but merely the residual effect of conducting business as efficiently and cost-effective as the technology and the ownership over these means permits. Private ownership over the means of musical production has redirected the creative process towards its own ends.

Perhaps paradoxically so, the efficiency administered through capitalism's labor relations that birthed the standardized drum set, is now slowly yet terminally, eroding the highly specialized skills involved in playing the instrument. As a drummer, to reject the virtual simulacra of their instrument is the means through which they can resist the erasure of their own economic viability as live performers. It is an attempt to preserve their own labor in an industry where they do not control ownership over these technologies or the manner in which most music will be produced in the very near future. The rationalizing precept espoused in the philosophy of Joseph Shumpeter's Creative Destruction holds little solace when it is one's own labor and means of survival is on the chopping block.[137] The issue is not the technology in and of itself but one rooted in the design of these tools, and how they are implemented to supplant the drummer within the digitally-mediated processes of modern musical production.

The practice of virtualizing the practices, spaces, and materials involved in making musical production more efficient is by no means limited to the drumset. Generative music-making software such as Boomy A.I., AIVA, and Amber, and A.I.-assisted music technologies such as Izotope's Izotope's Ozone 10, Neutron 4, and Tonal Balance Control 2, are becoming increasingly involved in the process of musical production. To many musicians, and throughout numerous discourses surrounding the topic, these assistive and generative technologies represent a potential existential threat to traditional forms of music making and production. Whether it be used to make musical production work more efficient, completely automating an editing task, or relying on a virtual mixing template to adjust and color recorded sounds, these tools have the potential to radically transform the way humans function within the music-making process - and by extension, the social relations embedded within real-time musical collaboration.

Indeed, these technologies exists at the level of producing, engineering, marketing, and consuming music of nearly every genre. While this could be seen as an existential

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137 Ziemnowicz, Christopher. "Joseph A. Schumpeter and innovation." *Socialism and Democracy* 2, no. 1 (1942): 2-4.

threat to the economic viability of being a working musician, it would be a reactionary stance to claim that these emergent tools are the sole cause of this experience or these feelings of precarity, impending joblessness, and increasing material scarcity. The precarious conditions for working musicians is certainly not a new phenomenon. They are perpetuated by the reifying mechanisms steering the commodification of music in a free-market economy, one which is centered around the aforementioned emphasis on efficiency, and undergirded by the wage-labor relations existing between employees and ownership.

These wage-labor relations are simultaneously the harbinger and perpetuator of these conditions, resulting in a paranoia towards the newest technological innovation designed for the automation of certain musical tasks, often leaving musicians feeling fearful of where these emergent tools will position their own labor within the processes of production. The scarcity of well paying jobs within the industry of cultural or musical production, as well as the relations between musical labor and ownership is a precondition to this rejection of technology. This rejection is not a result of the tools themselves but due to rapid increase implementation of their features that threaten to make the skills of the musician, audio engineer obsolete.

The processes involved in musical production are incredibly complex. Paradoxically, the myriad of creative and technical skills required for its completion have never been more demanding, yet the activities and individuals involved in these processes have never been more subject to isolation. Perhaps the greatest benefit that A.I.-assisted audio technologies provide musical laborers is the time to focus on exactly which of the manifold processes involved in music production that they wish. Musicians can now dedicate the majority of their creative effort on one particular part of the production process, rather than attempting to distribute their time, energy, and talents to, among other tasks, composing, arranging, recording , mixing, mastering and marketing their own creative work. This is especially important in an economy that is further alienating its creative labor, placing musicians, producers, and engineers into the role of the do-it-yourself, independent contractor. As Andrea Moore states in her essay "Neoliberalism and the Musical Entrepreneur," these market conditions necessitate an "ongoing need for the musician to create and maintain his or her own opportunities, seek funding, manage shifting schedules".[138] Perpetually manufacturing a career for oneself can be as much a full-time occupation as it is to actually create, perform, and produce the music itself. In this arrangement, the musician is assumed to possess a moral authority derived from their individual capacity to help themselves, acquiring the "ability to provide for their own needs and service their own ambitions".[139] In effect, the phenomenon of the bedroom studio musician is not the result of the masses of individuals choosing to work on every aspect of the production process themselves, but an emanation from market conditions that mandates musical entrepreneurialism. Under these conditions, some will succeed, but most will fail, as it requires an incredible amount of time, expertise, and training to be exceedingly talented enough to competently work within every dimension of music production. With this in consideration, if a particular musician wants to work solely on composing, then they can leverage A.I.-assisted (such as Izotope's *Ozone 10, Neutron 4*, and *Tonal Balance Control 2* software) technology to automate the mixing and mastering of the

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[138] Moore, A. (2016). Neoliberalism and the musical entrepreneur. *Journal of the Society for American Music*, *10*(1), 33-53.

[139] Brown, Wendy. Edgework: Critical Essays on Knowledge and Politics. Princeton, NJ: Princeton University Press, 2005.

recorded music, making the production process far more streamlined, efficient and cheaper than ever before. Conversely, if a mix engineer wants to refine their mastering or mixing skills, then they can rely on generative music software (such as *Amper Music*, *Boomy*, or *AIVA*) to quickly create music tracks. Researchers can use Recurrent Neural Networks to analyze a drummer's temporal consistency, or automatically transcribe their performance as well.[140] [141] [142]

No matter how real or applicable these fears regarding that A.I.-assisted music production software and generative musical tools are on an individual basis, it must also be realized that it is just the next technology in a long history of innovations with which musical labor has had to contend. The rejection of these emergent technologies and what they may potentially provide an artist has more to do with an ever present necessity and pressure to constantly recreate the working conditions of their labor so that they can derive whatever value that they can from their own productive capacity. To a large extent, a given musician's disposition to the creative and productive features afforded to them by these emergent technologies is entangled with, and inextricable from, their own political and economic conditions.

History is at once a fascinating story and an indispensable tool. The record and loudspeaker were once thought to be a threat to musical labor, as they could replace live

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140 Vogl, R., Dorfer, M., & Knees, P. (2016, August). Recurrent Neural Networks for Drum Transcription. In *ISMIR* (pp. 730-736).

141 Vogl, Richard, Matthias Dorfer, Gerhard Widmer, and Peter Knees. "Drum Transcription via Joint Beat and Drum Modeling Using Convolutional Recurrent Neural Networks." In *ISMIR*, pp. 150-157. 2017.

142 Vogl, Richard, Matthias Dorfer, and Peter Knees. "Drum transcription from polyphonic music with recurrent neural networks." In *2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 201-205. IEEE, 2017.

musicians with a simulacrum of their performance, one that could be reproduced in perpetuity. It was widely thought that this technological development could potentially eliminate the need for new music. Since the audience would not actually see the performers play, this new technology threatened the very notion of musical authenticity. Some of these concerns were very real and a few of them were somewhat imagined. Some of these fears even came to fruition. In most places in the United States it is rare to frequent restaurants or bars with live bands on a regular basis. As the number of venues for live performers continually diminishes, they are increasingly replaced with loudspeakers that feature a playlist from a music streaming service.

However, new technological developments also yield potentially unforeseen creative possibilities. The record and loudspeaker have become one of the most indispensable tools in creating and proliferating new musical practices, ones which represent a synthesis of geographically, politically, and socially disparate cultures. Aspiring musicians developed new performance practices by listening to records played back on loudspeakers. In some instances this was the only way to learn certain types of music (for example, Jazz) if a musician did not live in a major city or prominent economic center.

It would be difficult - nearly impossible - to conceive of a reality that did not include the loudspeaker, headphones, phone speakers, or a complex, networked infrastructure that facilitates the digital sampling and transfer of musical data. New forms of music and music-making practices are still created, stored, and shared not in spite of these technologies, but because of them. These new technologies also created completely new jobs, all which required a new set of skills. It is vital to not conflate the effect a technology will have on the industrialization of music and the creative potential it may provide for individual artists.

Another historical example is the digital synthesizer. In 1985, there were even attempts to legally limit the use of electronic music instruments in Swedish public spaces and recorded musics, spurned on by the Musicians' Union leadership of Sweden which claimed that the digital synthesizer would eventually eliminate the need for human effort in the process of music creations.[143] However, by the 1990's the digital synthesizer and other softwares had become situated as a core tool in the process of music production in the vast majority of the West, ultimately changing the way audiences perceive and qualitatively assess a given electronic musician's provenance or authenticity.

From Folktronica, to Nu jazz, to Neoclassical Dark Wave, to however one might describe Mason Bates's collaborations with Michael Tilson and the Youtube Symphony Orchestra[144], there are few western music genres that have not at least experimented with the use of the digital synthesizer. Whatever subjective value one assigns to this music is not as relevant to the fact that humans still drive meaning from actively producing and consuming music that is mediated though various layers of digital, analog, and emergent technologies.

One should not discount that there are examples of acquired skill sets that could once be used to sustain a career in the music industry that can now be nearly (or entirely) automated. However, these tools need to be delineated by their function in relation to

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[143] Fleischer, R. "“Mechanical music” as a threat against public performance." *work* 3 (2006): 01.

[144] Ritchey, M. Composing capital: Classical music in the neoliberal era. University of Chicago Press, 2020.

different stages and processes involved in the creation, production, distribution, and consumption of music. It is also vital that musicians are able to parse the multifaceted utility of Artificial Intelligence technologies, especially as they relate to the difference between the automation of musical production, and their creative application in the field of real-time improvisation and music creation.

A.I.-assisted audio technologies have a completely different effect on the creative space of real-time performance than they do in the labor of musical production and engineering. In music production, these new technologies can actually facilitate a renewed specialization and an increased focus and efficiency within established labor roles, while their implementation in the space of real-time music creation necessitates musicians learning a new sonic and gestural vocabulary through a renewed relationship to their instrument and spaces of musical collaboration. Perhaps a better form of resistance to persistently alienating and reifying economic forces is not to adopt a Luddite-like, reflexive rejection of emergent technologies, but to engage in the pursuit of building anthropocentric tools that position the human as the primary interlocutors between the digital and material space, to explore the outer limits of what new types of players and forms of musicianship these tools can create, and to stimulate novel discourses directed at accompanying and enriching these practices.

A comprehensive list of the planned future developments of the *Cybernetic Trap Kit* have not yet been determined in full, yet I have envisaged what the immediate next steps might be. My aspiration for the the next version of the software is to develop a real-time gestural recognition feature, which I have been working on in parallel with the last two phases of its development (described in Chapter Three). The motion tracking data I have generated through my own work with the software has been stored, and I plan on using it to eventually build a reference set that can be used with a gestural recognition feature. The camera input will take the input from the primary sensing device, run it through a layered neural network that will be trained to learn and correlate real-time hand motion to a library of gestures. Each of my gestures could then be recognized, or rather, matched to a gesture in the library, and subsequently mapped to enact a specific musical outcome. For instance, if a model is trained to recognize the ASL (American Sign Language) alphabet, then those gestures could be used enact a musical phrase played by a virtual synth or transition to another audio signal routing, to name only a few of the various applications. This is an especially exciting feature to build next, as it would represent a method of cueing intentional musical outcomes tightly mapped to a singular gesture, and would serve as an effective complement to the continuous control mapping provided by the motion tracking technologies already integrated into the system.

It could be said that one of the technological shortcomings of the software's current version is the lack of tools tracking motion occurring on the z-plane. Admittedly, this is a limitation of using a two-dimensional screen as the interface. And perhaps in the future, volumetric camera imaging, or point-cloud technology could be used in place of the current technological assemblage. Volumetric camera capture is an emerging technology that can represent a three-dimensional image in all directions, which can be accomplished by setting up multiple inputs, providing a comprehensive perspective of a subject and its actions.[145] Point-cloud video (PCV) captures subjects and their movement in space as a

[145] Zell, Eduard, Fabien Castan, Simone Gasparini, Anna Hilsmann, Misha Kazhdan, Andrea Tagliasacchi, Dimitris Zarpalas, and Nick Zioulis. "Volumetric video-acquisition, compression, interaction and perception." *Eurographics Assoc* (2021).

collection of data points in three-dimensional space.[146] These technologies would most certainly be a marked improvement over the two-dimensional constraints of commonly-used video technology, providing users with the ability to either observe or track their movement on the z-plane and monitor their activity from every captured direction. Having another dimension at one's disposal would certainly be useful, if for no other reason than to use vertical motion to process functional drumming gestures in real-time. However, implementing such sophisticated, nascent and extremely expensive technologies into a software designed for real-time music creation on a single laptop is currently impractical, to the point of being impossible for the vast majority of instrument designers and performers. Even if these new technologies signify that two-dimensional, screen-based interfaces are comparatively inferior from a purely technological standpoint, without the benefit of large grants and the interdisciplinary expertise of engineers, designers, researchers and artists, attempting to implement such technologies into a hybrid instrument that is specifically intended on keeping the physical technologies involved as pragmatic and financially accessible as possible, seems creatively counterproductive.

The current design reflects the immediate goals of the project, which are to provide drummers, and namely, myself, with a cybernetic means of processing their performance in real-time. With the exception of building the gestural recognition feature, the immediate future plans are to further demonstrate the musical viability of the *Cybernetic Trap* Kit. This includes diligently practicing with this software, developing more nuanced methods of interacting with the interface, building robust yet highly responsive parameter mappings,

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[146] "NYU Tandon Cuts a Rug with New 3D Video Technology," NYU Tandon, October 30, 2023, https://engineering.nyu.edu/news/nyu-tandon-cuts-rug-new-3d-video-technology.

better integrating the software into an existing drum set assemblage, and using this hybrid instrument as the conduit through which I can develop a vocabulary unique to my own sensibilities, experiences, and musical training. The goal of using a two-dimensional screen was to combine horizontal screen based motion with vertical drumming motion, which, in my mind, was certainly accomplished. The absence of tracking z-plane does not really have damaging musical consequences in this context. Furthermore, this dimension is somewhat accounted for in the velocity measurements tracked by the Sunhouse Sensory Percussion software (which, of course, determines the amplitude of each drum stroke). My plans are not to use another technology simply because it exists and might be better in some abstract way disconnected to the specific goals of the *Cybernetic Trap Kit*, but to fully explore the musical potential of this new hybrid instrument as it exists in its current form. The *Cybernetic Trap Kit* is an instrument unique to my musical goals, and the most effective method of improving the software and demonstrating its creative potential for other drummers is to become better at performing with it, not upgrading the video technology for the sake of doing so, or because anther technology exists that may be theoretically better, yet remains currently unpractical to implement. It will be interesting to see how these new video technologies will affect musicians' relationship to gesture in the future, but for now, trying to incorporate them into this particular technological assemblage would require a comprehensive, full-scale re-design of the *Cybernetic Trap Kit.*

Using the mechanical technologies and the advancing industrial might of the United States economy at his disposal, Ray Bauduc created a bespoke invention that enhanced the standardized drum assemblage, which ultimately altered the gestural and musical possibilities of the instrument. Creating digital tools to change the drumset assemblage is not only a continuation of this tradition, but enables drummers to gain a granular familiarity with their gestures and a deeper understanding of their effect on musical outcomes, all while simultaneously opening a whole new, modularized sonic world. In an economic environment predicated on rational managerialism, alienation, and cost-effectiveness, aspiring to build hybrid instruments that center these emergent technologies can represent a continuation and evolution of a rich and varied musical tradition rather than contributing towards its erasure in the service of purported efficiency and industrial progress. It is my hope that the *Cybernetic Trap Kit* has demonstrated this intention as a viable alternative to what current existentialist discourses around the future of musical labor have framed as inevitable.

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