The Shadow Harvester: Sonifying the Body Through Light

Darlene Castro
The University of Chicago
Chicago, IL, USA
dmcastro@uchicago.edu

Figure 1: Audience view of the *Shadow Harvester*.

Abstract

This paper explores the use of a violinist's shadow as input for a NIME prototype called the *Shadow Harvester*. For centuries, shadows have captivated humanity's imagination, and this project follows many artists, philosophers, and researchers equally captivated by the potential of shadows and silhouettes. This interface consists of a semi-translucent screen embedded with light-detecting sensors. These sensors register the movement of the violinist's shadow and produce data that can be mapped to generate, trigger, or process sound in Max/MSP. The *Shadow Harvester* turns a human shadow into a real-time, life-size avatar, splitting the attention of the violinist between their shadow self and carnal self. They are ensnared in a web of sensors that require the same attention as the visceral joints in their body because any movement carries sonic repercussions through either their physical body playing the violin or their shadow body "playing" this interface. The *Shadow Harvester* creates a highly entangled feedback loop between the violinist, centuries of violin performance practice, and composition. As such, it carries the potential to encourage new ways of incorporating movement into the folds composition, notation, and performance.

CCS Concepts

• **Applied computing** → Sound and music computing; • **Human-centered computing** → Interface design prototyping.

Keywords

NIME, Augmented Instruments, Performer-Technology Interaction, Light Sensors

1 Introduction

For centuries, arguably since we first huddled around fires, shadows have captivated the human imagination. They provide intangible evidence of our physical existence, giving objects depth and presence, both highlighting and obscuring. From brutal objectifications of entire races to canvases where we can imagine wondrous and terrifying creatures, shadows are pliable, amorphous and reflective art objects. Undoubtedly, shadows have occupied an extensive and ancient role in human culture and recent interactive art has also explored the use of shadows and silhouettes [7]. However, the use of a performer's full body shadow-silhouette as input for a digital music interface in a performance scenario has yet to be explored.

This paper discusses the *Shadow Harvester*, a NIME prototype that uses light detecting sensors to register the movement of a violinist's shadow-silhouette and uses that data to generate, trigger, and process sound. I begin by discussing the pervasive and extensive role shadows and silhouettes have occupied in human culture, highlighting their use across history. I also discuss related work that has explored the use of shadows for interfacing. Next, I discuss the aesthetic and technical considerations of using an analog, human shadow-silhouette as input for a digital music interface. I outline the aesthetic and practical decisions that guided the construction and design process, including specific implementations of the sensor data. Finally, this paper posits future research suggested by the *Shadow Harvester* and outlines design and construction improvements for future iterations of this interface.

2 Background

The primary aesthetic motivation for this project can be traced to Shigeyuki Kihara's *Siva in Motion* [10]. The work consists of a performance video featuring a figure donning 19th century European garb, dancing a traditional Samoan dance form— the *taualuga* [1]. As the figure dances, past frames slowly fade into the background and enshrine the performer's present position, as seen in Figure 2. It is this presentation and framing of the body that I wanted to capture and explore with this interface. This project is also indebted to a workshop using light-dependent resistors with Alex Christie, after which the imagery of Kihara's silhouette and the technology presented by Christie coalesced to form the *Shadow Harvester*. However, I would be remiss to exclude the influence stemming from centuries of shadow theatre and artwork. This section outlines the various cultural, artistic, and, at times, political roles that shadows and silhouettes have occupied. I will also discuss other artists and researchers who have interweaved shadows and silhouettes with technology.

Figure 2: Still from Siva in Motion

2.1 Shadows and Silhouettes

Greek scholars and writers tethered the shadow to the otherworld—and the soul— while artists as early as the Renaissance strived to show realism by depicting objects with their respective shadows to "give illusion to the flesh" [22]. Artists in the twentieth century manipulated and distorted shadows to lend a new perspective to everyday objects, elevating the otherwise taken-for-granted shadow to a state worthy of artistic attention [22]. In the 1814 novella *Peter Schlemihl's Miraculous Story* by Adelbert von Chamisso, a man trades his shadow for riches and finds that without it the world shuns him. However, he finds solace in the shadow theatre culture of Southeast Asia where *wayang* performers embrace his ability to manipulate puppets without producing a shadow himself.

The origins of shadow theatre and the shadow as a theatrical object are replete with conflicting theories and evidence [4]. Fan Pen Chen writes that although many mentions of cast shadows date back millennia, the origins of an established shadow theatre tradition are harder to pinpoint. Her research shows that shadow theatre techniques may have started with the nomadic people of Central Asia in the first millennium BCE. However, she clarifies that the first written mention of shadow plays occurs in India, at the tail-end of the first millennium BCE, though the earliest surviving shadow play script dates to 1243 AD. Copper plates dating to the years 840 AD and 907 AD reveal an already elaborate and sophisticated shadow theatre tradition in Indonesia, though Chen points to their predominant re-telling of two Indian tales the Mahabharata and Ramayana, as well as oral history, that betray Indian origins. Indonesian shadow theatre, in particular the Javanese tradition, contains a complex ecosystem enmeshing community, ritual, and history [8]. European shadow theatre emerged in the eighteenth century and was referred to as Chinese Shadows, although it shared hardly any similarity to actual Chinese shadow theatre traditions [8].

Asma Naeem presents a fascinating history of shadows and silhouette portraitures in the Early Republic [13]. Being much cheaper and more accessible, she writes that silhouettes became the most popular form of portraiture that countered the European monarchy and its aristocratic values. Furthermore, she writes that though they were a means of equalizing the population through artistic representation, not everyone enjoyed the same relationship with their silhouette portraits. Indigenous and enslaved people were not allowed the agency to keep their portraitures as heirlooms to be displayed, but rather were further objectified through their use in auction houses and phrenology textbooks [13].

Naeem writes that the both equalizing yet objectifying nature of portraitures made them rife to mirror the racial dynamics underlying the social and political systems contemporary to the Early Republic, further imbuing silhouettes with the paradox of "flatness and embodiment" [13]. Later on, artwork of black silhouettes against brightly colored backgrounds were used on the covers of pivotal publications by Black writers and artists of the Harlem Renaissance [3]. It soon became associated with Black culture and the jazz craze, making it alluring to white audiences who found coolness in its "…sense of kinetic energy, rebellion, attitude, and performance styles often associated with African American Culture." [3] Mehring further traces the lasting effects of this association to contemporary history, highlighting the visual markers found in Apple's early iPod ads with their bright backgrounds and dancing black silhouettes, as seen in Figure 3.

Figure 3: Apple iPod ad

2.2 Related Work

Other technological systems have explored the human silhouette as input for control and interfacing. Most notably, Myron W. Kreuger and his team developed the *Videoplace* project through the 1970's and 1980's, which projected the user's silhouette onto a screen and allowed them to navigate the computer through their silhouette's movement [9]. Pasquier et al developed the Shadow Agent to mimic more natural interactions via a shadow silhouette projected at the user's feet, acting as a sort of technological assistant, much like Microsoft's Clippy [21]. Yoshiyuki Miwa and their team sought out the user's shadow silhouette as a means to accurately portray and enhance the communication of body language in virtual conversations [12]. Likewise, Keizou Esaki and their team used the ability of the user's shadow to imply the presence of three- dimensional objects and mitigate the uncanny effects of using realistic avatars in virtual communication [5].

In a series of works contained within *Lighthouse* (2004-2005), Yolande Harris moves through the vast potential of light sensors in a variety of interactive and non-interactive configurations [6]. Jaime E. Oliver's Silent Drum is a controller that uses the silhouette of an elastic drumhead to activate sound. As the elastic is depressed by the hand it creates a silhouette that is then analyzed through a video camera and mapped onto sound synthesis and playback [14]. Likewise, Golan Levin and Zachary Lieberman developed a system that generates sound in response to hand silhouettes that are projected onto a screen and registered by vision-based software [11]. Christian Jacquemin et al. have shown yet more methods artists and researchers have implemented with digital shadows to create various installations and performances, while at the same time presenting their own software and approach [7].

Figure 4: Rear-back view of the *Shadow Harvester*

3 The *Shadow Harvester*

The aesthetic impetus for this interface makes it imperative for both the audience and performer to experience the same visual object of the shadow. Equally important is that the shadow act as an interface object of its own, not just a visual byproduct of an interaction. In other words, it is not the *body* that must interact with the sensor, but rather the body's *shadow*, an important distinction for the performer. Though other sensors and visual motion capture technologies can offer higher fidelity in tracking a violinist [20], the ability to use a deliberately visible silhouette as a control mechanism provides a compelling reason to use analog light sensors despite their lack of precision. In this section I outline the physical construction of the *Shadow Harvester* and offer a basic strategy for developing a sensor layout on the screen. Lastly, I highlight how the sensors behaved and what programming configurations worked best in early experiments.

3.1 Construction and Design

The *Shadow Harvester* consists of a semi-translucent screen placed between the audience and the performer, with the performer facing the audience through the fabric (see Figure 4). Shrouded in darkness, the performer is lit from behind with a strong LED flashlight, as incandescent lights create shadow aberrations along the shadow's outline. The light source is placed approximately ten feet behind the performer to result in a relatively true-to-size silhouette. The screen construction itself borrows heavily from shadow theatre techniques. It consists of fabric, in this case fabric typically used for window shades, that is both firm and densely woven to catch as much light as possible on its surface and provide minimal see-through. Although the fabric is thick, it is still translucent enough to allow light to pass through, allowing for clearly outlined and darkly shaded silhouettes to appear.

There are three main sensors used in light detection— photoresistors, photodiodes, and phototransistors. Out of the three, the phototransistor is the most sensitive, but has the second best response time [2]. The phototransistor and a 100K resistor were soldered onto custom cut 13x13mm breadboards (see Figure 8) where shielded wires connected them to an Arduino Mega 2560 Rev3 microcontroller according to the circuit diagram shown in Figure 5. Figure 6 shows the flow of data from the sensors to a computer, as well as the softwares used. Max/MSP received integers between 0 and 1023, but this range can be scaled and expanded with basic mathematical operations which can be combined for powerful programming configurations.

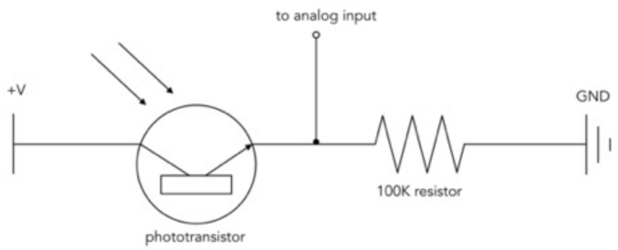

Figure 5: Circuit diagram

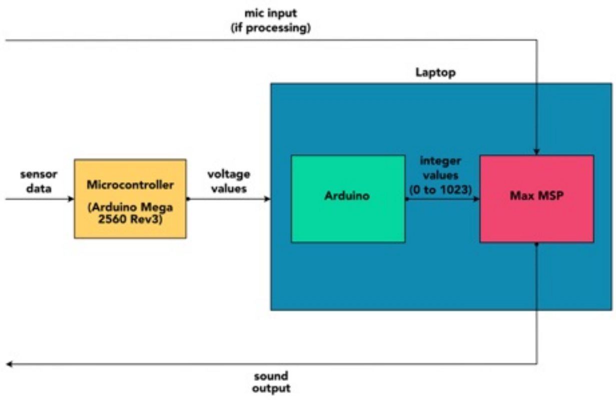

Figure 6: Workflow diagram

As stated before, this project relies on the aesthetic imagery of cast shadows on cloth— a reliance that leaves little visual space for hardware. As such, the sensors and wiring themselves become aesthetic issues. This problem was partially solved by the use of embroidery hoops. Embroidery hoops consist of two interlocking circles and have been used for centuries to provide tension to fabric for various textile arts. The hoops work much like drumheads: the smaller circle is placed behind the fabric while the larger circle is placed in front of the fabric, pulling it tight over the smaller circle. A small screw tightens the larger circle to apply pressure between the fabric and both circles. These hoops provide a visually decorative shadow pattern on the screen and provide small channels behind which wires and sensors can be hidden, as shown in Figure 7.

Figure 7: Wires routed behind embroidery hoops

Though this particular iteration of the project is for a standing violinist, a pivotal goal of the project was to create a system that can be adapted to any instrument played in any position by any performer. This is important from an accessibility standpoint, but also as a means of pushing back on the costs and materials incurred. Here the goal is to have a flexible system that reuses technology and materials already in use, lessening the financial burden when creating new versions of this system. The embroidery hoops are perfectly suited to a modular design and can be rearranged to suit various configurations. Similarly, a 3D printed sensor housing unit, shown in Figure 8, allows for movable sensors and small amounts of temporary adhesive made it easy to change layouts for different configurations.

3.2 Sensor Topography

Calibrating the *Shadow Harvester* requires specific information from the performer's body to properly plan and place sensors. Body measurements and photos of the violinist were used to map a general layout for sensor placement. In this particular configuration for a standing violinist, height, arm (from shoulder to elbow), and forearm (elbow to first finger knuckle) measurements were taken. Apart from these measurements, systematically taken photos of the violinist were analyzed to arrive at a skeletal/nodal outline of the performer's anatomy and identify axes of motion, as shown in Figure 9 and Figure 10. Figure 11 shows superimposed skeletal positions simulating the violinist's path of movement, a preliminary analysis that could provide valuable insight into potential sensor placement on the screen. Placement along heavy-traffic areas of motion, or areas of motion often found in established violin performance practice, provides ample opportunity for high sensor interaction. However, if minimal interaction is preferred, trying to avoid motion within these

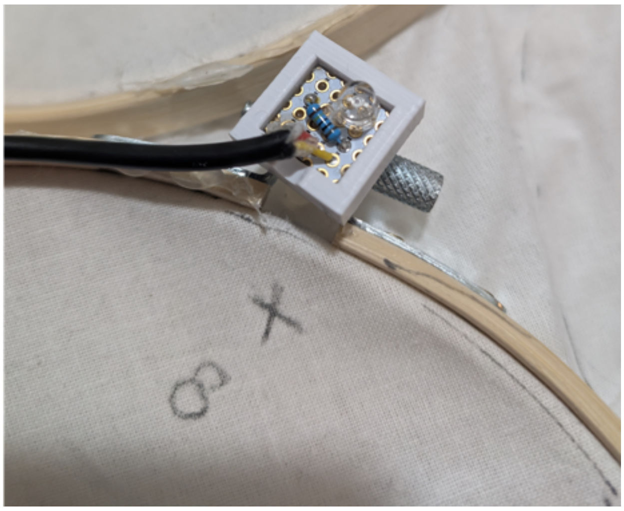

Figure 8: Close up of sensor housing unit

high-traffic placements proves to be more difficult and becomes a constraint. Likewise, sensors placed along low-traffic areas require a different level of intent to reach, carrying the potential for constraint and additional attention from the performer.

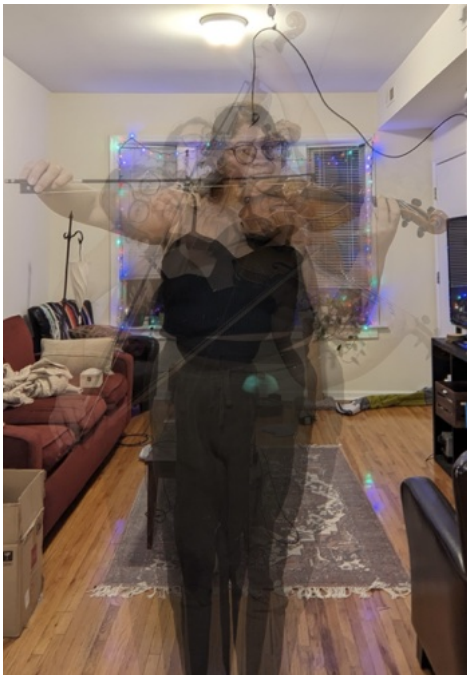

Figure 9: Superimposed pictures of violinist playing the violin

These sensors create a network that provides rich opportunities for incorporating body movement into the creative fold of composition and interaction. Most of the nodes are anatomical in nature— joints made of muscle, tendon, and bone filled with an entire life's worth of experience. However, the violin becomes a type of joint, giving the performer's body another external fulcrum point that restricts movement. It goes beyond serving as an extension of the body— it is integrated into performer's aggregate body and acts similar to all other viscera in charge

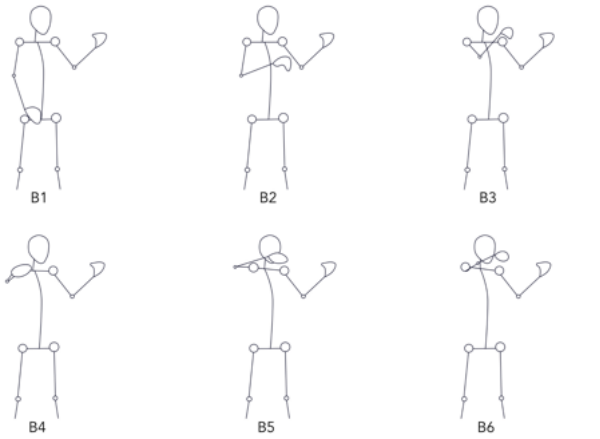

Figure 10: Skeletal outlines

Figure 11: Superimposed skeletal outlines simulating movement

of motion. The sensors on the screen also act as quasi-fulcrum points around which the performer must plan movement. In a way, the screen adds itself to the body at a distance, placing itself, like a shadow, onto the body. This all suggests the necessity to situate this interface with pre-existing movement and gesture theory, a topic which is, unfortunately, beyond the scope of this paper.

3.3 Implementations and Limitations

The *Shadow Harvester*, at its core, is a system for gathering numerical data from the interruption of light. This, paired with its modular design, makes it open to a wide range of sonic possibilities and applications. However, in preliminary tests the phototransistors proved to be imprecise and it became nearly impossible to attain a consistently exact data set. Readings from the phototransistors were consistently between 0 and 300 when covered by the shadow. Likewise, a sensor fully exposed to light consistently read from roughly 850 to 1000. Figure 12 shows a graph of multiple readings for covering a sensor at roughly the same distance from the screen [18].

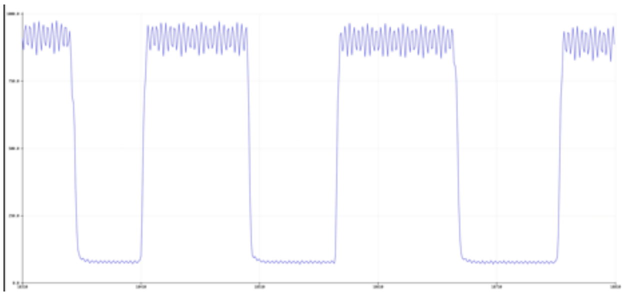

Figure 12: Graph of sensor data taken from Arduino's serial plotter

Though the sensors were unable to produce exact data, a rather strong generalization could still be attained that effectively ensured any reading below 350 was correctly identified as a shadow. However, this meant that the sensors were unable to consistently register any changes in quality of shadow. The intensity of a shadow changes according to the performer's distance from the screen, a distinction the sensors, unfortunately, could not reliably register. Similarly, the light source itself, as well as ambient light, also influenced the threshold value of the sensors. As such, three particular implementations were attempted in this first test of the prototype that essentially rendered the sensors to work like individual triggers, conditional networks of triggers, and a knob.

Treating each sensor as an individual button that activates a single action proved to be one of the most successful implementations of the data [17]. Placing the threshold at 400 accurately identified any shadow covering the sensor at multiple distances from the screen. The sensors also worked well as conditional networks where specific combinations of sensors controlled a particular activation [15]. Though this paper only explored sound playback, it is feasible that the sensors could also actuate other sonic actions, such as controlling the (pre-determined) volume of playback or changing pre-determined parameters of sound processing or synthesis. Due to the sensor's lack of precision, treating them as knobs proved less successful. Consistent data was not only hard to replicate, but difficult for the performer to intuit and control.

Two instances of knob implementations were tested, one with multiple sensors controlling the parameters of a delay and another with multiple sensors controlling a field of oscillators whose frequencies are shifted by 20hz according to scaled data from the sensors. It was clear that the delay was reactive to the movement of the performer, but any precise control was difficult to achieve [16]. Likewise, when using the sensors to control the frequency of oscillators, it was clear they reacted to movement, but any control or clear logic to pitch change was difficult to achieve [19]. These preliminary tests showed the difficulties of using light sensors as knobs, but further experiments may uncover better results. Though the sensors did not reliably generate specific or stable streams of values, they did fluctuate well between the upper and lower limits of a range and if used effectively could still retain some functionality similar to a knob.

4 Future Research

The *Shadow Harvester* is rich in avenues for future exploration, most clearly in developing the interface for other instruments.

Scaling down the interface for the use of hands or scaling up to include more instrumentalists could provide ample opportunity to test how the interface translates to other configurations and sizes. Likewise, 3D printing could facilitate new shapes and designs for the embroidery hoops, and offer better cable management potential without the need for an adhesive. Other improvements include better latency, sensor color coding for the performer, and experiments with different or additional light sources. It might also be possible to use the light sensors in combination with other high-fidelity sensors to retain shadow interfacing, but gain better control. However, one of the largest areas left to explore is the performer's perspective and experience with the interface.

In addition to the attention the performer allocates to producing sound on their acoustic instrument, they must now consider how that same movement will interact with the sensors via their shadow avatar. Where before the large sweeping motion of an arpeggiation held mostly sonic meaning, now the consequences of how that motion produces sound via the sensors must also be considered in early stages of composition. Previously, the performer's attention, as it pertained to their body, was one of a first-person view of themselves playing their instrument. Now they must also account for their body via the third-person perspective of their projected shadow avatar. This constant switching between perspectives could provide valuable insight into how this interface alters performance practices. This in turn could encourage composers to reexamine the link between movement and sound production on both the physical instrument and the shadow interface, deepening the already-present entanglement of the electro-acoustic composition process.

5 Conclusion

Throughout human history the meaning and symbolism of the shadow spans numerous eras, cultures, and disciplines in its remediation. It is a visual object that has enticed humanity for centuries, acting both as an irrefutable aspect of our everyday life and a heightened cultural object. As this paper has covered, various scholars have shown how the silhouette has been morphed to serve political, philosophical, artistic, and mystical means. It has infiltrated our contemporary technology and cast off into the virtual world with researchers creating avatars every bit as ephemeral and intangible as their shadowy counterparts. This interface prototype has shown that light sensors, despite their lack of precision, are a viable mechanism through which a full-body shadow silhouette can act as an interfacing object. With its deceptively simple components, this interface creates a complex system of entanglement where the addition of shadows explodes the body and performer's attention into larger interconnected webs, whose nodes occupy the space of both carnal, digital, and technological viscera. It is not just capturing the body through light, it also has the possibility to alter an entire ecosystem of performance, including notation, performance technique, stage presence, and instrumental movement. Guided by the commitment to using shadows and light sensors, the *Shadow Harvester* has the potential to deepen the entanglement between instrumental performance practice, electro-acoustic composition, technology, and the body.

6 Ethical Standards

A series of workshops and performance with the interface were funded by the Chicago Center for Contemporary Composition and The University of Chicago Music Department. No conflicts of interest were identified. All researchers, performers, and participants took part consensually in the activities outlined in this paper.

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References

[1] 2014. *Shigeyuki Kihara's "Siva in Motion".* Retrieved April 11, 2024 from https://lacma.wordpress.com/2014/03/26/shigeyuki-kiharas-siva-in-motion/
[2] Obagade Thompson Adewumi. 2022. Comparative Analysis of Photoelectric Characteristics of Photosensors: A Case Study between Photoresistor, Photodiode, and Phototransistor. *IOSR Journal of Applied Physics* 14, 3 (2022), 01–12.
[3] François Brunet (Ed.). 2017. *Circulation.* Terra Foundation for American Art, Chicago, IL, US.
[4] FP Chen. 2003. Shadow Theaters of the World. *Asian Folklore Studies* 62 (01 2003), 25–64.
[5] Keizou Esaki, Shota Inoue, Tomio Watanabe, and Yukata Ishii. 2015. An embodied entrainment avatar-shadow system to support avatar mediated communication. In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN).* 419–424. https://doi.org/10.1109/ROMAN.2015.7333615
[6] Yolande Harris. 2006. Inside-out Instrument. *Contemporary Music Review* 25, 1-2 (2006), 151–162.
[7] Christian Jacquemin, Georges Gagneré, and Benoît Lahoz. 2011. Shedding light on shadow: real-time interactive artworks based on cast shadows or silhouettes. In *Proceedings of the 19th ACM International Conference on Multimedia* (Scottsdale, Arizona, USA) *(MM '11).* Association for Computing Machinery, New York, NY, USA, 173–182. https://doi.org/10.1145/2072298.2072322
[8] Ward Keeler. 1987. *Javanese Shadow Plays, Javanese Selves.* Princeton University Press, Princeton, NJ, USA.
[9] Myron W. Krueger, Thomas Gionfriddo, and Katrin Hinrichsen. 1985. VIDEOPLACE—an artificial reality. *SIGCHI Bull.* 16, 4 (April 1985), 35–40. https://doi.org/10.1145/1165385.317463
[10] LACMAUnframed. 2014. Siva in Motion. Retrieved April 14, 2025 from https://www.youtube.com/watch?v=ephfsBQ0voc&ab_channel=LACMAUnframed
[11] Golan Levin and Zachary Lieberman. 2005. Sounds from shapes: audiovisual performance with hand silhouette contours in the manual input sessions. In *Proceedings of the 2005 Conference on New Interfaces for Musical Expression* (Vancouver, Canada) *(NIME '05).* National University of Singapore, SGP, 115–120.
[12] Yoshiyuki Miwa and Chikara Ishibiki. 2004. Shadow communication: system for embodied interaction with remote partners. In *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work* (Chicago, Illinois, USA) *(CSCW '04).* Association for Computing Machinery, New York, NY, USA, 467–476. https://doi.org/10.1145/1031607.1031685
[13] Asma Naeem, Penley Knipe, Alexander Nemerov, Gwendolyn Dubois Shaw, and Anne Verplanck (Eds.). 2018. *Black Out: Silhouettes Then and Now.* Princeton University Press, Princeton, NJ, USA.
[14] Jaime Oliver and Mathew Jenkins. 2009. The Silent Drum controller: a New percussive gestural Interface. In *International Conference on Mathematics and Computing.* https://api.semanticscholar.org/CorpusID:12936979
[15] Darlene Castro Ortiz. 2025. Example of conditional sensor networks performing basic addition. Retrieved April 14, 2025 from https://youtu.be/936gUbEFgRA
[16] Darlene Castro Ortiz. 2025. Example of sensors mapped to parameters of delay. Retrieved April 14, 2025 from https://youtu.be/IT9_pgFCCPU
[17] Darlene Castro Ortiz. 2025. Example of sensors triggering playback. Retrieved April 14, 2025 from https://youtu.be/setS2gyT1fA
[18] Darlene Castro Ortiz. 2025. Sensor data taken from Arduino's serial plotter. Retrieved April 15, 2025 from https://youtu.be/S4J81rmefM8
[19] Darlene Castro Ortiz. 2025. Shadow Instrument Demo. Retrieved April 14, 2025 from https://youtu.be/MWjLq2PoLPE
[20] Dan Overholt. 2012. Violin-Related HCI: A Taxonomy Elicited by the Musical Interface Technology Design Space. In *Arts and Technology*, Anthony L. Brooks (Ed.). Springer Berlin Heidelberg, Berlin, Heidelberg, 80–89.
[21] Philippe Pasquier, Eunjung Han, Kirak Kim, and Keechul Jung. 2008. Shadow agent: a new type of virtual agent. In *Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology* (Yokohama, Japan) *(ACE '08).* Association for Computing Machinery, New York, NY, USA, 71–74. https://doi.org/10.1145/1501750.1501766

[22] Victor I. Stoichita. 1997. *A Short History of the Shadow.* Reaktion Books, London, UK.