Ballet Hero: Building a Garment for Memetic Embodiment in Dance Learning

James Hallam
Georgia Institute of Technology
247 4th St. NW
Atlanta, GA 30332-0155
jhallam@gatech.edu

Alison McKenna
Georgia Institute of Technology
247 4th St. NW
Atlanta, GA 30332-0155
amckenna@gatech.edu

Emily Keen
Georgia Institute of Technology
247 4th St. NW
Atlanta, GA 30332-0155
emily.ann.keen@gatech.edu

Mudit Gupta
Georgia Institute of Technology
247 4th St. NW
Atlanta, GA 30332-0155
muditg@gatech.edu

Christa Lee
Georgia Institute of Technology
247 4th St. NW
Atlanta, GA 30332-0155
xalee@gatech.edu

Permission to make digital or hard copies of part or all of this work for personal classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. for all other used contact the Owner/Author.
Copyright is held by the authors.
ISWC'14 Adjunct, September 13 - 17, 2014, Seattle, WA, USA
ACM 978-1-4503-3048-0/14/09.
http://dx.doi.org/10.1145/2641248.2641269

Abstract
This paper describes the analysis and design of a wearable technology garment intended to aid with the instruction of ballet technique to adult beginners. A phenomenological framework is developed and used to assess physiological training tools. Following this, a garment is developed that incorporates visual feedback inspired by animation techniques that more directly convey the essential movements of ballet. The garment design is presented, and a discussion is provided on the challenges of constructing an e-textile garment using contemporary materials and techniques.

Authors' Keywords
Wearable technology; dance instruction; ballet; phenomenology; embodiment; on-body feedback.

ACM Classification Keywords
H.5.2. User Interfaces: User-centered design.

Introduction
To ask what allows a dancer to be able to dance is to invite a discussion of embodied movement. Embodiment in this case refers to the recognition of the movements as being part of the self – the choreographed movements being performed without much higher-order thought behind them. Dancers have rehearsed these motions so thoroughly that they know the sequences that lead one to the other, and can recognize the feeling of

Figure 1: A dance instructor corrects her student.

Figure 2: A staged ballet class in the lab.

them seamlessly linking together. But novices find this concept challenging – they have no embodied knowledge of these movements, and have no idea what it will feel like should they ever perform them correctly.

A teacher, therefore, is trying to communicate to a new student of dance what it feels like to dance correctly: what it feels like when their own embodied movement takes hold of their body. We have no method for communicating this data directly, from one brain and body to another, so decades of dance training have built up abstracted ways of tackling the problem – using an intermediary language of gesture, symbols, metaphors, and touch. With guidance, time, and repetition, a student can slowly begin to accumulate the experiences that lead to embodied motion, and begin to dance with confidence; but we raise the question – with all of the recent advances brought by placing technology on the body, is there no way to improve this process?

We began by considering the potential of an interactive garment that could augment the relationship between teacher and student, and developed an evaluation framework to guide our initial exploration. Any technical solution would need to be guided by Verbeek's work on technological mediation, particularly the embodiment and hermeneutic relationships[5]. It would need to draw on aspects of Csikszentmihalyi's concept of Flow, or the persistence of a pleasurable state balanced between boredom and challenge[1]. Finally, it would need to follow Norman's guidelines for a conceptual model comprised of affordance, constraints, and mappings, providing an intuitive tangible interface[2].

Exploration

To begin, we staged a ballet class. One of our team members had spent 14 years prior to joining our program pursuing ballet training, and was able to guide our group through a basic ballet lesson. We recorded the session, and noted all of the ways our instructor used to communicate the basics of ballet movement to the rest of the group, none of whom had danced before. We immediately noticed how she relied on demonstration and metaphor to explain the core ideas, and how she would correct our position by speaking and touching the part of the body that needed attention. It was clear that there were no absolute positions at play here, but that everything was relative to one's own body, and different for every dancer. At one point, while expressing the challenge of communicating the deeply embodied movements, our instructor commented "I can't even talk about it, I don't know what I do."

Figure 3: A photo series showing the individual elements of a fondu, and a composite showing how a dancer thinks of the movement in a single chunked progression.

Figure 4: An early concept of the interactive model, using an accelerometer to trigger keyframes.

As we progressed through the lesson, we saw two elements reliably come into play: chunking and mirroring. Chunking represented the ability to take individual movements, and string them together into a sequence that could be symbolically referenced with a name[4]. As chunking is a key element of visuomotor sequencing, it was not a surprise to discover how many of the basic building blocks of ballet were chunked – it was our instructor's job to break them down until we could deal with the chunk as a whole. The lesson used repeated versions of this, breaking complex movements into simple parts, and then recombining them until they could be performed as a unit.

The second element we explored was mirroring. We possess a phenomenological sense of embodiment as it relates to our ability to move relative to other human beings, a supposition supported by research into the mirror neuron system in the pre-frontal cortex[3]. This system fires not only when we move our own body, but when we observe the movements of other human beings. This symmetrical mapping is one of the ways in which we are able to mimic other people's movement, and we saw this in play out in our lesson, as each of us would attempt to match the cadence and position of the instructor.

What we saw here was that the instructor possessed a wide array of tools, but all of them were delivered through a very real world presentation of the alterity relationship[5]. Even as we responded to her feedback, it was difficult to get a sense of any of the hermeneutic data, the absolute positioning of our bodies, and especially difficult still to sense the embodied movement she was trying to communicate.

Proposal

Following this investigation, we proposed to build a garment that supports the natural alterity relationship of teacher and student, while supplementing that feedback with a better-developed embodied relationship. We wished to accomplish this while providing essential affordance, constraints, and mapping to support the learning environment while provoking and maintaining flow state. We proposed to do this in part by taking advantage of mirrored synchronous movements that established a natural embodied connection between student and teacher, that used effective management of chunking to decrease the initial complexity of the visuomotor sequencing, and that could be gradually altered to increase the challenge of the learning environment as the user became more adept.

To reduce the visual complexity of the instructor's movement, we turned for inspiration to Norman McLaren's "Pas de deux", a revered dance film

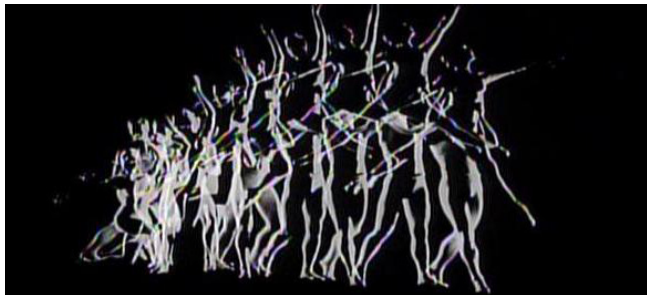
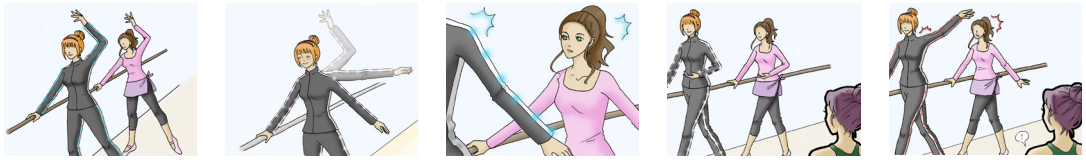


Figure 5: Pas de deux © 1968 National Film Board of Canada. All rights reserved.



The instructor demonstrates moves that the student attempts to mimic.

As the instructor moves a limb, the start and stop of the movement is lit on the garment.

The student notices the keyframes and tries to match timing and position.

An assistant watches the student and observes how the student mirrors the teacher.

If the student is out of sync, the assistant can flash a corrective error message.

Figure 6: Storyboard demonstrating use of the garment

Figure 7: A circuit layout in production, showing the free motion quilting foot used to route the circuits.

made in 1968 that used lighting and compositing techniques to visually flatten the bodies of a pair of dancers and overlay their movements. The result is an onion-skinning effect that clearly draws the contours of the performers' bodies and movement in three-dimensional space, simplifying and amplifying their positions. We recognized the potential of visual simplification, and began to envision a set of high-contrast markings over the body to partially reproduce this effect in the real world.

Our last challenge was to more effectively deal with the chunking problem, allowing the student to focus more readily on the dominant limb that was moving in any combination. To accomplish this, we looked for inspiration in the world of animation, which uses key frames to establish dominant positions of movement, and tweening frames to fill in the gaps. During our test lessons, we had identified that it mattered more that the students started and stopped in the correct places, than the exact nature of how they moved between those spaces. It became apparent that we could use these key frames to highlight the important points at the beginning and end of any given movement, and measure the student's performance against their ability to follow in sync with the instructor from one key frame to the next.

Interaction

As we looked for ways to apply our findings, we began to devise a garment intended to be worn by an instructor teaching a student. By using this garment as a communication tool, we hoped to be able to keep the student's attention on the teacher, and give them the opportunity to feel connected to the teacher's movements by moving in sync. We began sketching out a system that would light up the instructor's limbs, breaking each basic movement down into starting and stopping positions. By allowing the student to focus on the key frames, we hoped to reduce the complexity of the individual elements, and encourage them to see the movement as one continuous chunk. Through this, we hope for the student to feel better connected with the embodied movements of the instructor.

We intend to use an assistant to observe the lesson and watch for errors in synchronicity. We will provide them with a tool to trigger error lights on the limb of the instructor, indicating to the student the limb they should focus on. Using an assistant provides us a mechanism for feedback while avoiding the complexities of automating the system.

Garment Design

The garment design is dominated by a high-contrast stripe running up the legs, torso, and arms of the instructor, playing off of the shin lighting in "Pas de deux". Each stripe is lit from underneath

Figure 8: Placement of primary components on the garment.

Figure 9: Each limb featured a set of sewn bus lines, providing power and I2C data to component patches.

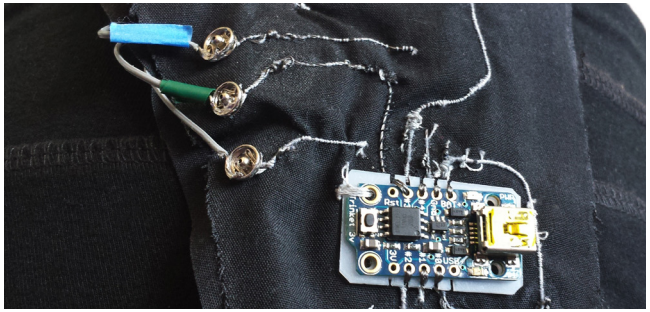


Figure 10: To gain flexibility and modularity with the circuit design we use nickel snaps to make junctions.

with a set of individually addressable RGB LEDs, and can be controlled independently. Each limb is controlled by its own microcontroller paired with an accelerometer, which senses changes in movement, and uses this data to trigger the LEDs. There are four microcontrollers, each of which is connected to a central microcontroller placed on the back, which is capable of reading and sending data from each of the limbs using the I2C protocol. We use this central controller to receive wireless control signals, and send the error messages to individual

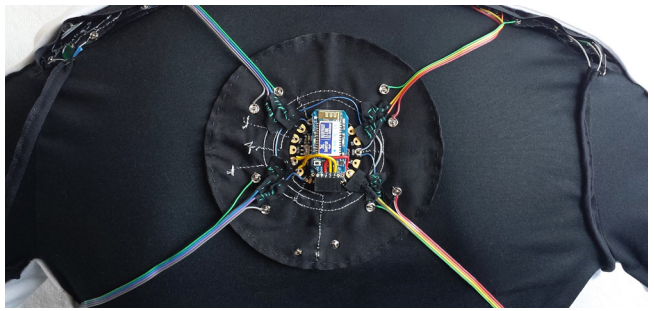


Figure 11: The central microcontroller provides power and I2C data connections to each of the four limbs.

Figure 12: Detail showing the indicator lights arranged along the arm of the garment.

microcontrollers, which flash patterns visible to the user. All of the technical components across this garment are connected together by a network sewn out of conductive thread, with the ability to modify and upgrade the garment as the requirements of the garment are changed.

Discussion

This project has aimed to embed a complex interactive model into a full-body research garment, built primarily using e-textile materials

Figure 13: A demonstration of the garment in a training context.

Figure 14: The garment in motion.

and techniques. The prototype that we documented in this paper is functional and performs well under many of the informal tests we have subjected it to in the lab, and we continue to refine the garment as we move towards broader testing.

Durability of the circuit connections has posed an occasional problem for us over the development of the project, as many of the circuits are joined with hundreds of hand-tied knots. The garment in its intended use is designed to feature the full range of motion of a dance instructor – the performance of which currently leads to occasional unexpected flashes from the LEDs as the fabric stretches and twists underneath them. We are working towards eliminating any of this unexected stimuli, with the goal of a formal test of the core dance theory presented in the paper.

Conclusion

We worked to construct a conceptual model for dance training designed to aid adults beginners starting ballet, and used this framework to inform the creation of a garment platform we presented here. We now intend to build a scaled-down version of the LED array in a form factor with fewer hand-sewn connections, suitable for conducting a stable experiment in a dance studio setting. By splitting the garment production research and the dance training experiment into separate investigations, we hope to gain insight from each of them that will let us develop a final garment that meets the long-term goals of the project.

Acknowledgements

We would like to acknowledge Professor Jim Budd for his supervision and support on this project. We would also like to acknowledge the contributions of Thad Starner and Clint Zeagler for their instruction in wearable computing. We would also like to acknowledge Mika Satomi and Hannah Perner-Wilson for kobakant.at, from which we have learned so much.

References

[1] CSIKSZENTMIHALYI, M., 1990. Flow: The psychology of optimal performance New York: Harper and Row.

[2] NORMAN, D.A., 2002. The design of everyday things. Basic books.

[3] ROHRER, T., 2007. The body in space: Dimensions of embodiment. Body, language, and mind: Embodiment 1, 339-378.

[4] SAKAI, K., KITAGUCHI, K., and HIKOSAKA, O., 2003. Chunking during human visuomotor sequence learning. Experimental Brain Research 152, 2, 229-242.

[5] VERBEEK, P., 2007. Beyond the human eye: Technological mediation and posthuman visions. Mediated Vision, 43-53.

[6] WARD, G., 1989. Classical Ballet Technique. University of South Florida Press, Tampa, FL.