TECHNOLOGY IN ACTION™

# Practical Fashion Tech

## Wearable Technologies for Costuming, Cosplay, and Everyday

Joan Horvath
Lyn Hoge
Rich Cameron

Apress®

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*This book is dedicated to Lyn Hoge's family, biological and extended, for the laughter, adventure, support, and love. They have been there through the good and the bad and have always generously shared their intelligence, joy, and creative ideas.*

# Contents at a Glance

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# About the Authors

**Joan Horvath and Rich Cameron** are the cofounders of Nonscriptum LLC based in Pasadena, California. Nonscriptum consults for educational and scientific users in the areas of 3D printing and maker technologies. Joan and Rich are particularly interested in finding ways to use maker tech to make scientific research cheaper and more accessible to the public.

This book is their latest collaboration, following their earlier works *Mastering 3D Printing* (Apress, 2015), *The New Shop Class: Getting Started with 3D Printing, Arduino, and Wearable Tech* (Apress, 2015), *3D Printing with MatterControl* (Apress, 2015), and *3D Printed Science Projects* (Apress, 2016). They also teach online classes in 3D printing and maker tech for LERN Network's U Got Class continuing education program. Links for all of the above are on their website, www.nonscriptum.com.

In addition to her work with Rich, Joan also has an appointment as Core Adjunct faculty for National University's College of Letters and Sciences. She has taught at the university level in a variety of institutions, both in Southern California and online. Before she and Rich started Nonscriptum, she held a variety of entrepreneurial positions, including VP of Business Development at a Kickstarter-funded 3D-printer company. Joan started her career with 16 years at the NASA/Caltech Jet Propulsion Laboratory, where she worked in programs including the technology transfer office, the Magellan spacecraft to Venus, and the TOPEX/Poseidon oceanography spacecraft. She holds an undergraduate degree from MIT in Aeronautics and Astronautics and a master's degree in Engineering from UCLA.

Rich (known online as "Whosawhatsis") is an experienced open source developer who has been a key member of the RepRap 3D-printer development community for many years. His designs include the original spring/lever extruder mechanism used on many 3D printers, the RepRap Wallace, and the Deezmaker Bukito portable 3D printer. By building and modifying several of the early open source 3D printers to wrestle unprecedented performance out of them, he has become an expert at maximizing the print quality of filament-based printers. When he's not busy making every aspect of his own 3D printers better, from slicing software to firmware and hardware, he likes to share that knowledge and experience online so that he can help make everyone else's printers better too.

**Lyn Hoge** has been a dance teacher, costumer, and choreographer for over 40 years. In that time, she has designed and created costumes for musicals, plays and various types of dance performances. These include everything from simple period costume plays like *Our Town* to elaborate and quirky versions of *The Rocky Horror Picture Show* and *Bat Boy the Musical*. Lyn has also created unique and functional designs for everything from the T-Rex and Woolly Mammoth in *The Skin of Our Teeth* to stilt walkers at the Edinburgh Fringe Festival. In the past couple of years, she has been delving into the world of wearable tech and is writing about her experiences as a teacher and a student. Lyn has a BA in dance and has studied at UCLA, UCI, and at many private studios.

# Acknowledgments

This book draws heavily on the open source hardware and software communities. First, we want to acknowledge the contributions of the Arduino community worldwide, particularly the many useful tutorials and background information at www.arduino.cc, and the community behind the Fritzing software (www.fritzing.org), which we use for many illustrations. The consumer 3D printing ecosystem would not exist in its current form without the open source 3D printing hardware and software community, which we as always are grateful for as the basis of much that we have built upon in our work. We have endeavored to attribute open-source material accurately wherever it appears and apologize for any inadvertent omissions.

The maker community as a whole has also been very supportive. The picture of Joan and Rich in the "About the Authors" section was taken at the 2015 San Mateo Makerfaire by Ethan Etnyre; we appreciate all the inspiration we have gotten by looking at projects made by everyone at maker events.

The Apress production team, past and present, made this process seamless for the most part, and was there with virtual needle and thread for the occasions where it was not. We dealt most directly with Mark Powers, Michelle Lowman, Corbin Collins, Natalie Pao, Jessica Vakili and Welmoed Spahr, but we also appreciate the many we did not see.

We thank the staff, teachers and students of Windward School in Los Angeles, particularly to those in Lyn's 2015-2016 theater costuming class where many of these concepts were tried out in early form, as well as Lyn's department chair, Jordon Fox. The owners, past and present, of Make Believe costuming in Santa Monica, California, were very helpful in discussions of what makes a good costume. Bill Doran, cofounder of Punished Props, was also generous with his time in giving us ideas of what to include in Chapter 12. Others have given us permission to use their images or ideas, and we credit those gifts where they occur.

Finally, we are grateful to our friends and families for putting up with the disruption of a maker book in progress and supplying pizza interventions when needed. The book has been a wonderful creative ride for the three of us, and we appreciate everyone on each of our individual roads to this point.

# Introduction

This book is a collaboration between two technologists (Joan and Rich) and a veteran teacher, costumer, and choreographer (Lyn). The three of us take turns narrating different chapters and sections. Fashion tech can require skills in design, pattern-making, sewing, electronics, programming, and 3D printing. Besides the tech skills, making a good costume or accessory also requires knowledge of the intangibles of what makes a good costume. We know that people come to fashion tech and wearable electronics from a variety of directions, and that any given reader may know a lot about one part already. We have structured the book so that you can easily skip a chapter or two if you are very experienced in that particular art already.

There are many books in this space that present sets of projects. We have those too, but we wanted to focus on showing why things are done a certain way so that you can figure out how the techniques might apply in other situations. The technology is changing fast, and there are many new components to play with all the time; the key thing is to know the general assumptions behind how they are designed, and where you are most likely to find information on how to use the latest thing. There are many good resources out there on how to sew, how to 3D print, and how to use an Arduino. We felt that the missing part was bringing them together in one readable volume.

We wrote this book with several audiences in mind. First, if you are already someone interested in creating great costumes for theater, or you like to go to cosplay conventions, you will be able to use the material in this book to make your creations interactive, illuminated, or wherever you choose to go with the technologies. If, on the other hand, you are passingly familiar with Arduino electronics but have no idea how to sew or assemble a garment, you can fill in your gaps and learn how to design the overall project.

If you are a high school or college teacher who needs to create a "Fashion Tech," "Costume Tech," or "Wearable Electronics" course, Appendix A has some suggestions that you could use to get started. The material in this book would also work well as the basis for a summer camp session that would mix traditional sewing and crafting with some electronics and coding. One caveat is that the electronic components are delicate and pricey compared to traditional craft materials—they are not toys. Most manufacturers suggest a minimum age of 13 or so to use their products, with adult supervision, and we suggest the same.

One of the challenges in fashion tech is that you need a lot of stuff. First, you need a sewing machine, or you need to stick to projects that start from an existing garment or that are small enough to hand sew.) You will need to purchase the electronic components required, and you will need access to 3D-printing services for those projects. We have tried to design the projects so that you can try things out with as little hardware as possible for any given project.

The big temptation in doing a first project is to do something big and complicated. That is a bad idea, because without experience it can be very hard to debug projects that

mix sewing, electronic circuits, and software. We devote almost a whole chapter (Chapter 10) to deconstructing our first collective project, which was far too ambitious, it turns out. To reduce the temptation, we provide first projects that are fun and open-ended so that you can add more if you would like, or stop when you feel you have a product you are happy with.

To cover all this ground, we divide the book in four parts. The first part, "The Big Picture," sets the stage for the rest. Chapter 1 gives our view of what fashion tech comprises and talks about how the three of us work together as a model for you to build your own team. Chapter 2 then gives a broad introduction to what makes a good theatrical costume, assuming that is how many will apply this material.

Moving on to Part II, "The Basics," we introduce the key skills needed for wearable tech. Chapter 3 introduces hand and machine sewing basics, with many references to other resources. Chapter 4 focuses on the art of creating and using a sewing pattern. In Chapter 5 we switch over to the tech side and give an introduction to electronic components. In Chapter 6 we see how to program these devices. Finally, in Chapter 7 we bring it all together in a comprehensive but manageable project to create a hostess apron with a built-in timer that flashes a red light on the apron when the timer is counting down, and a green one when time is up. These chapters are enough to create "blinky" projects—garments that light up with some minimal ability to control the lights.

Part III, "Beyond the Basics," explores more sophisticated topics. Chapter 8 reviews the different types of sensors that are available to make your project react to its environment and introduces some other hardware, such as motors, that is beyond the scope of this book to review in detail but that we think you should know about generally.

Chapter 9 summarizes the 3D-printing process and gives pointers on where to learn about it in detail. Chapter 10 talks about our experiences trying to create an overly complex project (a dress with a mind of its own) without adequate planning.

If you are thinking of going straight to Chapter 11's bigger projects (we know, we would have thought about it too), resist the urge and read Chapter 10 first. Speaking of Chapter 11, there you will find the dress from this book's cover, which uses electroluminescent (EL) ribbon to light up the boundaries between fabric blocks. This is an intermediate sewing project and requires no circuit design or coding. The other project in that chapter takes an off-the-shelf hat and adds circuitry to it so that it lights up red if you shake your head no and green if you nod your head yes. The hat project requires minimal sewing. Thus you can pick a substantial project based on where you feel most secure.

Finally, in Part IV, "Where to Go from Here," Chapter 12 looks at other technologies we did not capture elsewhere in the book but that are frequently used in amateur costuming, like laser cutting, foam armor creation, and vacuum forming. Chapter 13 winds up the main part of the book with a look at some high-end current projects and some speculations on where the field may go in the future.

We have also included two appendices. Appendix A has details about how you might think about laying out one project-focused class of varying length to teach all the pieces of fashion tech. Appendix B captures all the links in the book in one ready reference.

There are several Arduino sketches in this book. They are available for download. Instructions are on the copyright page of this book.

We hope you enjoy trying out the aspects of fashion tech that are new to you, and we hope to see many projects in the future. If you create something cool based on this book, you can tweet it to Joan on her `@JoanHorvath` Twitter account, or contact us at `www.nonscriptum.com` to let us know. Now, start reading and make something awesome!

PART I

# The Big Picture

These first two chapters provide some background about what makes a good costume (or other garment) design. Chapter 1 introduces fashion tech and talks a bit about how the rest of the book is arranged. Chapter 2 focuses on what makes a good costume and suggests things to think about in garment design in general.

CHAPTER 1

# Fashion Tech

Fashion tech is an interdisciplinary field that merges traditional fashion and textiles with modern electronics, software, and other technologies. In this book, we consider fashion tech to mean interactive garments or accessories that incorporate electronic components, or that were created using digital fabrication technologies like 3D printing. Technologies like these have only recently become available at the consumer level because of advances in the production of electronics that have lowered the cost of computers, sensors, and light-up components that can be embedded into everyday objects. This chapter introduces fashion tech and talks about how you can use this book to get started as a practitioner in this new field.

## A Brief History of Fashion Tech

Creating clothing to protect ourselves from the weather has been an inspiration for technology development since antiquity. Tools have gone from bone awls for punching holes in leather, to spindles for creating yarn, to the looms that could produce vast amounts of fabric at industrial scale. Figure 1-1 shows an 1875 stereoscopic photograph of the Amoskeag (New Hampshire) Gingham Mill weaving room. (There is an animation of this stereo image at `http://stereo.nypl.org/view/14480`).

**Electronic supplementary material** The online version of this chapter (doi:10.1007/978-1-4842-1662-0_1) contains supplementary material, which is available to authorized users.



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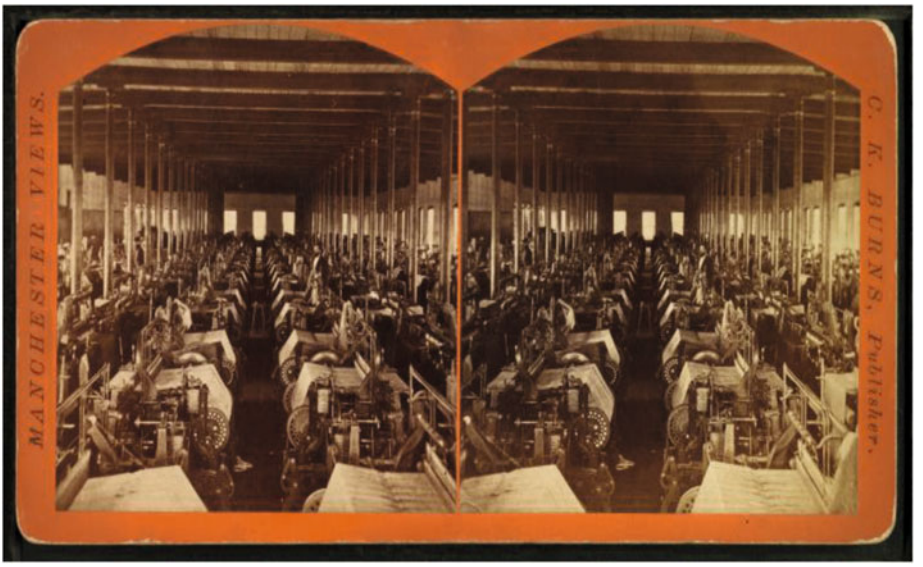


***Figure 1-1.*** *Weaving, circa 1875. From the New York Public Library (http://digitalcollections.nypl.org/items/510d47e1-7c18-a3d9-e040-e00a18064a99)*

The desire to create elaborately patterned fabrics led to the development of the Jacquard loom in 1801. A weaver created cards with holes in them that controlled (through an ingenious system of lightly tensioned springs and wires) the patterns the loom was creating. This allowed automatic generation of very elaborate patterns such as brocades.

Fancy fabrics for drapes and wedding gowns is not the end of the story, though. English mathematician and inventor Charles Babbage saw the Jacquard loom punch cards and wondered if a similar system could be used to create a more general computing machine for mathematical problems, which he called the Analytical Engine.

Babbage first described the machine in 1837; the full machine was never actually created (https://en.wikipedia.org/wiki/Analytical_Engine). Nevertheless, Babbage is widely seen as the inventor of the general-purpose computer, and the descendants of its punched cards were in use well into the 1970s. And so, the computer has its birth in Victorian fashion tech!

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■ **Tip** If you are interested in the history of textile technologies, check out the amazing historical archive with many illustrations and original documents at www.cs.arizona.edu/patterns/weaving/index.html. More specifically, if you would like to download a Victorian-era book on how to create the cards for a Jacquard machine, E. A. Posselt's *The Jacquard Machine Analyzed and Explained* (Posselt, 1893) is now in the public domain and available from the Hathi Trust Digital Library at http://hdl.handle.net/2027/gri.ark:/13960/t26b0d33d.

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The introduction of the integrated circuit in the late 1950s and its rapid evolution have now resulted in affordable computers that are comparable in size to coins. The late Gordon Moore predicted in 1965 that the performance of computer chips would roughly double every two years based on technology improvements; Moore's Law, as it came to be called, has been remarkably accurate (so far). This means that early-1980s supercomputers are outclassed by 2016 single-board computers that are a few inches across and cost $5.

Other digital electronics have kept pace, and tiny processors and sensors developed for smartphones, cameras, and other devices now make it possible to unobtrusively include as part of a hat or apron processing power that would have had been ministered to by dedicated staff in the 1980s. Coming full circle from the Jacquard loom, it is now possible to have circuits woven into clothing. (We talk about Google's Project Jacquard in Chapter 13.)

Another side effect of access to cheap, easy-to-program electronics has been the rise of robotics-based consumer products, like low-cost consumer 3D printers and computerized home sewing machines. 3D printers in turn make it easy to prototype physical objects quickly and cheaply, and are leading to even more innovation. Feature-laden home sewing machines can enable complex projects that would have been too much for the hobbyist in the past.

The bottom line of all this is that you have access to a fantastic array of technologies to make cool projects. In this book we focus on using digital electronics and related technologies (such as 3D printing) in fashion applications like creating costumes and other interactive wearable pieces.

# Costuming

Now that it is possible to make a more elaborate and professional-appearing costume at home, it is not surprising that *cosplay*—dressing up as and role-playing a favorite fictional character—has become something of a subculture, initially in Japan but rapidly spreading to the United States and elsewhere. Science fiction and other kinds of conventions often have cosplay fans attend as their favorite character. Anime and video game characters are favorite subjects. Given that, there are many opportunities where an otherworldly effect is desired, and the technologies in this book might be just the thing to take a cosplay costume to the next level.

Historical costuming has always been always popular. Renaissance Faires (`www.renfaire.com`) have popularized historical re-enactment of activities of the late Elizabethan era and dressing up as a person from that time. Visible electronics might be out of character, but there could be a dragon on your arm with glowing eyes or a head that turns toward the light.

You may be reading this book for ideas on enhanced theatrical costumes, either for school productions (as Lyn talks about later in this chapter) or for professional use. At the school level, costumes likely need to be low-budget, assembled quickly, and easy to get in and out of for a ten-year-old with stagefright. A few strategic special effects enabled by electronics can make a costume memorable. For example, Lyn and her students added programmable glowing eyes to fish for *The Little Mermaid*.

***Figure 1-2.*** *Plastic armor in its box*

Finally, there are just plain dress-up costumes for parties, holidays, and so on. Figure 1-2 shows custom-made, vacuum-formed (Chapter 13) plastic armor as it looks in a box, and in Figure 1-3 it briefly transforms Sir Rich to his true knight-errant identity.

***Figure 1-3.*** *The armor fitted on our knight-author*

Some costume elements such as masks (Figure 1-4) or a period dress can take a person to another place and time. If you have a fantasy costume anyway, why not mix it up and make it interactive? (Armor and masks courtesy of Make Believe in Santa Monica, California; we talk more about them in Chapter 2.)

***Figure 1-4.*** *Masks*

Maybe you are not looking to make a costume, per se, but are looking to do something functional—a wall hanging that lights up as a night light when it gets dark, maybe, or strategic LEDs inside a bag so you can find your keys at night.

Our point in all this is that the first step in applying the technologies in this book is to think about what you are trying to do and how you want it to look. Too often people start out wanting to use a technology for its own sake, but that often does not end well. Just because it is possible to make an interactive garment or art piece, why should you?

If you are reading this book you may be planning to build costumes like those we just described. Or you may have been asked to develop a class for high school or college students. If you are a teacher or parent, fashion tech projects can be a good way to convince students who otherwise might have been scared off electronics or programming to give them a try, motivated by the final product.

# Our Design Philosophy

We (Joan, Rich, and Lyn) came into this field from very different directions. Rich is a Millennial who grew up designing electronic projects (including one of the forerunners of today's consumer 3D printers and a small, elegant 3D printer still being sold by a company Rich and Joan used to work for—you can see one in Chapter 9). He likes to make things for their own sake, the usual definition of a *hacker*. (In the circles we travel in, *hacker* does not have a negative connotation. The people who do bad things with their skills are called *black-hat hackers*.) Rich is very detail-oriented and has encyclopedic knowledge of the hardware and software we cover in this book.

Joan comes to this as a recovering rocket scientist, and her role is to keep the big picture in mind and think about how to avoid going into too much detail in any one technical area. She worked on spacecraft to other planets, where one tiny mistake could cause disaster. So she brings structure and experience working on complicated systems, and also the desire to make explanations as simple as possible (while still being correct).

Lyn comes with long experience making costumes for middle and high school productions. Besides the ability to apparently whip up costumes out of a pile of fabric plus thin air, she has a sense of humor and a keen eye for when a small detail might make all the difference. She has also taught sewing in a classroom and so knows what pitfalls might arise.

The three of us take turns guiding you through the book and switch into first person for much of the book when we focus on one person's particular expertise. Sometimes we collaborate too closely for any one of us to take the lead, and there (as we do here) we will just say *we*.

We are walking through our backgrounds here (there is more in the "About the Authors" section at the front of the book) because we suggest that you build a team to work on your first projects that has all these aspects, though not necessarily spread across the team the way it happens to be with the three of us. Good chemistry and a sense of humor are also important for a team to have. Sometimes things just come out looking silly, and you have to laugh, figure out what went wrong, and not do *that* again. At other times you may need to let one of your team members go off in a corner and try things for a while. But if one of us got stuck, we found it valuable to articulate what the problem was to the others, and we could go back to first principles and try to think about what we were trying to accomplish.

# Planning Your Projects

There are many books out there that cover different aspects of making a fashion tech project, and many projects on the Internet that you can try. We felt an orderly path was missing, starting with the basics of sewing, plus electronics hardware and software, to allow someone who knows very little about the skills needed to get started on projects.

We always emphasize the idea of *system design*. It is very easy to come up with a great idea for part of a project, but doing that part the way that you would if it was not incorporated into something wearable might be very different than the way you should start out to incorporate it into a dress or hat. We cannot emphasize enough the need to plan out a complex project end-to-end ahead of time. Chapter 10 tells the story of the first project we did together in which we largely ignored this principle—even though all three of us knew better.