CHAPTER 11

Robotics and Manufacturing

The topic of robots can be a fantastical or functional conversation, depending who you're speaking to. For a long time, science fiction has been dreaming of the ways in which robots might look like us, talk like us, think like us, and take over the world. In reality, most of the machines being built in the field of robotics have nothing to do with the portrayals on television. The most useful robots in industry today are not humanoid, aren't **bipedal** (walking on two legs), don't speak, and don't think like humans.

Robots in Popular Culture

> *We're fascinated with robots because they are reflections of ourselves.*
>
> —Ken Goldberg, professor, UC Berkeley

Robots in popular culture have given consumers the image of a humanoid robot that looks as beautiful as Scarlett Johansson or is an assassin, as in *The Terminator.* We should challenge these portrayals for a number of reasons: they're both inaccurate and have a negative social impact.

L. Luce, *Artificial Intelligence for Fashion*,
https://doi.org/10.1007/978-1-4842-3931-5_11

By depicting robots this way, we do not accurately represent what robots are capable of. Media portrayals ignite fear instead of sparking curiosity. In medicine, the Da Vinci robot, shown in Figure 11-1, is capable of completing operations with higher precision than a human alone. In space, the Opportunity rover, also shown in Figure 11-1, was built to survive just a few weeks but has been pinging back video to Earth for over 13 years. These robots look nothing like the replicants from *Blade Runner* but have led to progress in their respective fields without posing any threat to humanity.

On the flip side, building humanoid or anthropomorphized robots has proven to increase consumer trust in these machines. In certain contexts, like elderly care, this can be a positive goal to work toward if we can get past the **uncanny valley** of it all.

Figure 11-1. *The Da Vinci robot (left) and the Opportunity Robotic Rover (right). Images courtesy of Da Vinci and NASA/JPL, respectively.*

Robots and Women

> *I can love, I can speak, without somebody else operating me. You gave me eyes, so now I see. I'm not your robot. I'm just me.*
>
> —Miley Cyrus, singer and songwriter, lyrics from *Robot*

The portrayals we create of robots as humans have ethical consequences for the professional and personal lives of many people. One of the most obvious examples of this impact is through gendered representations. I am not the first to call out that the patterned portrayal of women as sexy, nonthreatening, and passive robots in both Hollywood productions and as AI assistants is unethical.

We often assign AI assistants female names like Alexa, Siri, or Cortana. We see films with sexualized female robot characters like Rachel in the original *Blade Runner*, Ava from *Ex Machina* in Figure 11-2, or Samantha from *Her*. We even build female robots for entertainment or pleasure, like Sophia from Hanson Robotics in Figure 11-2, Project Aiko, EveR, Actroid, and so many more.

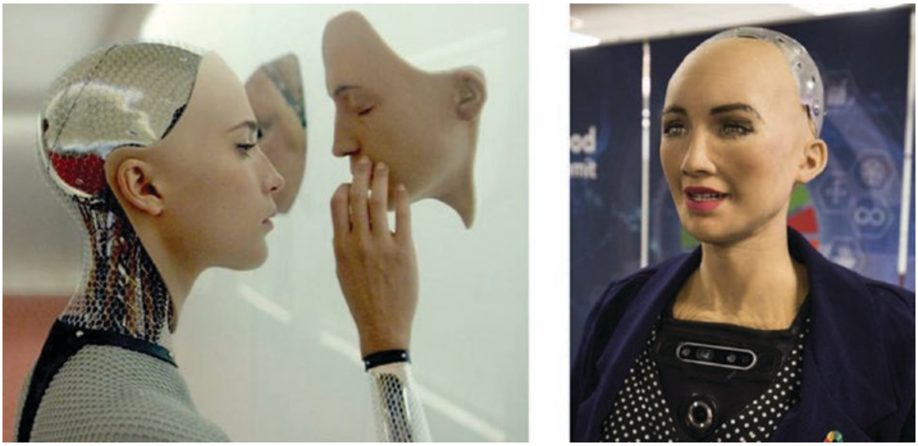

Figure 11-2. *Ava from the feature film, Ex Machina (left), and Sophia from Hanson Robotics (right). (Sophia image courtesy of ITU Pictures from Geneva, Switzerland.)*

This is not to say that there are no male robots. HAL 900 from *2001: A Space Odyssey* is just one of many examples. The question is why the robots represented as female are sexualized servants rather than having any accomplishments of their own? Why is it that there is no masculine equivalent word for the term **fembot**?

You may disagree with this premise, but the point is simply that none of us are exempt from responsibility when bringing these ideas and machines into the world. As creators, we should think about what we're presenting and the impact that it has on the psychology of the people around us. There are already biases prevalent in our culture. Proliferating these ideas within devices that we live and work with is leaving an impression on their users. The creators are the individuals who are responsible for the impact these devices have.

It is rather humorous to reflect on humans being the only species on earth that could create a machine that looks like them and be fooled by it.

What Is a Robot?

The term *robot* has been applied loosely to many kinds of devices. There is a constant debate even among industry experts as to what truly defines a robot. For some, it is simple enough to describe a robot as a programmable machine that carries out complex actions. For others, a robot is really the physical embodiment of artificial intelligence that takes action in the physical world. The word *autonomous* comes up a lot as a descriptor. In short, there is no perfect definition.

Types of Robots

There are many ways to categorize robots. They can be organized by industry: medical, space, entertainment, and manufacturing, for example. They can also be organized by the way they move: by wheels, walking, flying, swimming, or stationary, not moving at all.

In manufacturing, the types of robots that we're usually referring to are **industrial robots**. These are robots that are specialized for functional tasks, like moving and assembling parts in a factory or warehouse. They're usually stationary and by means of the types of tasks they carry out are often mounted to the ground.

Industrial Robots

Industrial robots were originally built for a wide range of tasks, usually relating to rigid mechanical parts. The types of operations these machines typically perform are things like welding, assembly, inspection, packaging, and deburring. These relate to materials like plastics, metals, and cardboard, on a basic level in sheet or block form.

Articulated Robots

The most prevalent industrial robots are **articulated robots**. Usually this type of robot is a jointed arm with several **degrees of freedom**. Articulated robots can be used for very complex tasks. The body of these robots is referred to as a **manipulator arm**.

Choosing the correct robot for a particular task is important. Most robotic arms have a low **payload capacity**, which just means that they cannot lift things above a certain weight. In fashion, this is generally not an issue, as garments usually weigh under a couple of pounds. In other industries that deal with heavier materials like blocks of metal, payload capacity can be a major constraint.

There are typically five major components on a robot: a **control system**, sensors, **actuators**, **power supply**, and **end effectors**. Figure 11-3 shows a diagram of these components on an articulated robot. The control system and sensors are not shown in the image because these components can be mounted in various locations on the arm. The control system (also called controller) is often located in the base and sensors may be integrated throughout the arm depending on application.

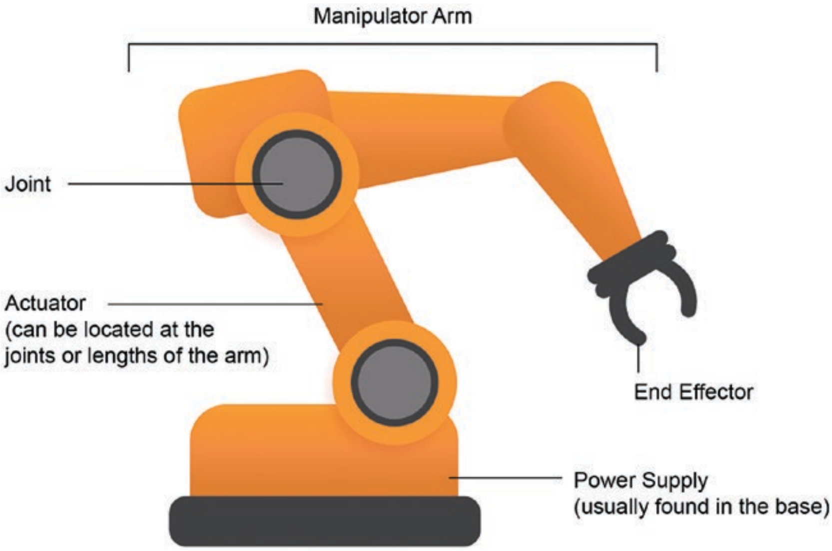

Figure 11-3. *A simplified diagram of a manipulator arm based on its major components*

Material manipulation is handled by the end effectors. An end effector is the “hand” of the robot arm. In robotics, choosing the right end effector for the task is akin to choosing the proper foot on a sewing machine.

End Effectors

End effectors often play a major role in determining whether a technology can handle a material. For instance, an end effector that will be used to pick up screws is a very different tool than one that would pick up grapes. In fashion, this is especially challenging due to the way fabric deforms when it is moved. Picking up a piece of fabric leads to an infinite number of possibilities in terms of the specific shape and number of creases the fabric might take on. Figure 11-4 shows different types of end effectors that might be used in a traditional robotic system like grippers and vacuum cups. Tools like screwdrivers, welding guns, drills, and spray guns are also common end effectors in manufacturing environments.

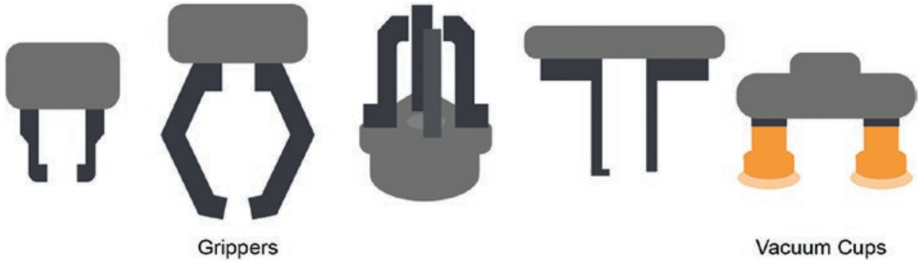

Figure 11-4. *A variety of end effectors, such as grippers and vacuum cups, used for different applications in robotics*

Sewing Robots

SoftWear Automation, an Atlanta-based robotics company focused on sewing, uses a combination of a table and manipulator arms with end effectors to move fabric both during and between sewing operations. In this system, the table itself is actuated with a series of vacuum-based components that move up to four layers of fabric, depending on the weight and pile. A close-up of the sewing head can be seen in Figure 11-5.

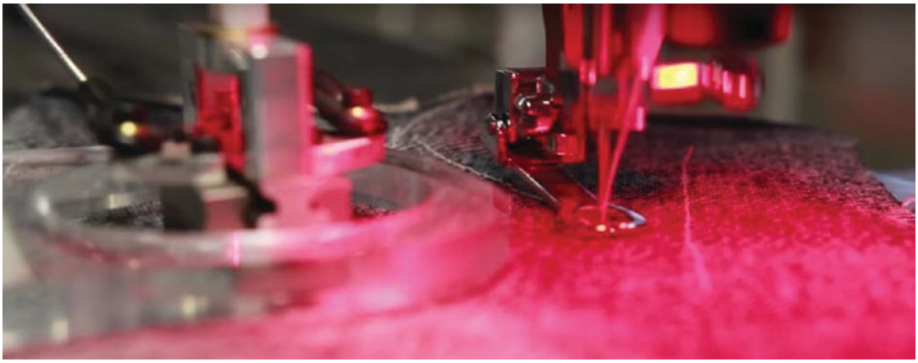

Figure 11-5. *A close-up of the SoftWear Automation sewing head, which uses computer vision to guide the fabric through sewing*

By implementing computer vision at the head of each sewing machine and at other points in the system, the sewing tables created by SoftWear Automation are able to manipulate and sew even complex curves. Keeping the pieces of a garment or other soft good flat on the table reduces the amount of deformation that the system will have to manage in sewing. Figure 11-6 shows one of the **gantry robot** (also referred to as a **cartesian robot**) tables used at SoftWear Automation.

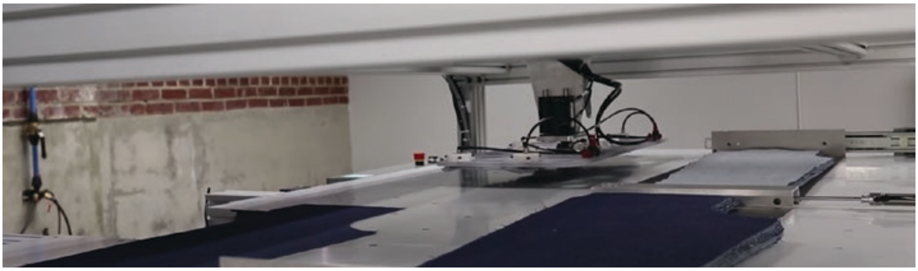

Figure 11-6. *A gantry-based system for moving fabric pieces across the sewing table*

SoftWear Automation uses multiple techniques in a sewing system to completely automate the production of specific goods. Figure 11-7 shows both the gantry-based system for moving textiles across the table and a manipulator arm that is mounted to the gantry and can pivot the fabric to bind the edges during sewing.

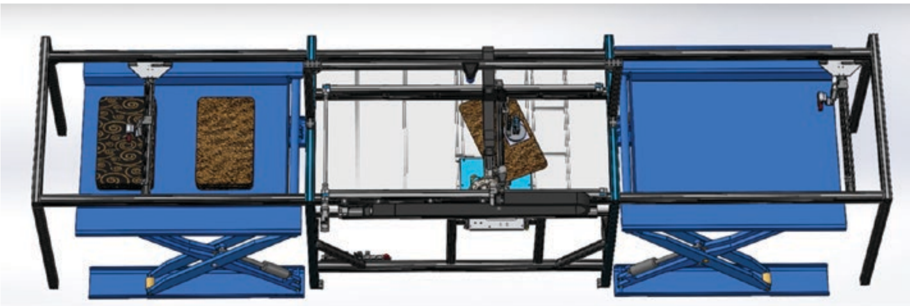

Figure 11-7. *The SoftWear Automation sewing system for binding the edges of car mats*

The deformation of the materials is not the only challenge in robotic sewing. Sewing operations are incredibly high speed, at around 5,000 stitches per minute. To navigate these challenges, the hybrid systems built by companies such as SoftWear Automation are different from other types of robotic manufacturing.

Advantages of Robotics in Sewing

Palaniswamy Rajan, chairman and CEO of SoftWear Automation, has presented several advantages to robotic sewing: cost reduction, **reshoring** production, addressing globalization, environmental impact, and adding manufacturing flexibly to resolve issues like fit.

In the United States, most of our manufacturing has been outsourced to overseas vendors. Over time, the areas of the world that once provided high-quality and inexpensive sewing labor, like China, are growing into economies that look much like the United States itself. That means the wage delta is decreasing over time and so is the willingness to do tedious and taxing labor for low wages.

There are other inefficiencies in the textiles-to-garment industries. America is the third largest producer of cotton in the world. Yet, most of the goods that we consume made of cotton have been imported. Typically, we send our raw cotton goods overseas to be turned into textiles, sewn into garments, and then shipped back, because that is more cost-effective in terms of dollars. One of the unfortunate consequences is the environmental impact that has. While it may seem obvious that we could simply manufacture these goods in the United States and avoid the complicated logistics, manufacturing in America has decreased dramatically over the past 50 years, and we could neither compete on cost or volume with the current reliance on labor. Robotic automation of sewing tasks provides a way to decrease labor costs and increase throughput while manufacturing local to the source of raw materials, in the United States and other nations.

Each garment can be made one piece at a time using these robotic systems. In contrast, traditional manufacturing occurs in batches that have minimum quantities per size in order to meet cost efficiencies. By making each item one at a time, certain variations can occur without a change in the cost efficiency. Each can be a different size, and to the robot, it doesn't make a difference.

Designing for Robots

In this new era of robotic production in the soft goods space, we'll have to keep in mind new design principles when it comes to designing for robotic manufacturing. Over time, we will see an increase in the use of robots for apparel manufacturing.

It's also important to bear in mind that as a field, robotic sewing is still nascent. In terms of design, not every variation of every type of garments is possible just yet. For now, brands will have to keep things simple.

Automation and Robotics

Robotics and **automation** are not synonymous. Automation can occur in software alone, not requiring physical robotic hardware at all. Robotics can also be used to do things other than automate tasks, though they are commonly used for automation. Automation is primarily with the goal of having a machine to automatically complete tasks. Robotics generally has a more responsive approach and a goal to gain results within an imperfect world.

The distinction is usually that robots can be used to carry out a range of complex tasks, not just a single operation. They can also sense and react to real-world inputs.

On the flip side, industrial automation techniques may refer to a pocket-setting, which can only set pockets. If something should be set up incorrectly in those manufacturing environments, the machine will not respond. The autonomy of a robot to respond based on sensing the real world is part of what makes it a robot and distinct from other types of automation.

Questions of Responsible Automation

The conversation around robots replacing people in the workplace has seeded concern around how to introduce responsible automation. What will employers do to train the workers they are currently employing for new jobs rather than displacing them? Will robotic automation support a movement toward made-to-order manufacturing rather than mass manufacturing? There are many questions for a future fashion industry to answer.

Supply-Chain Robotics

Robots are being used beyond the factory floor in the fashion industry. Already, in warehouses around the world, robots have made their way into **picking and packing** procedures. From Tencent and Alibaba to Amazon, billions of dollars have been invested in building robotic automated infrastructure to manage the redundant task of finding inventory items and putting them into a box to ship to customers.

Kiva Systems is a well-known example of robotic automation in warehousing. They were acquired by Amazon in 2012 and renamed Amazon Robotics. Before the acquisition, they were being used by major corporations across the fashion industry, including Saks Fifth Avenue, Gilt Groupe, The Gap, and more. Today, there are a number of companies like Kiva Systems such as AutoStore, Dematic, and OPEX.

These robots are typically considered to be part of a school of thought that robots should be working alongside humans rather than replacing them. This idea is commonly referred to as **collaborative robotics**.

Historically, industrial robots have been large, metal robots. This made them dangerous to humans, because a human who stood in front of a robot could easily be hit unknowingly by a robot arm. Some collaborative robots, soft robotics, are made from soft materials to avoid this. Others may be equipped with better sensing mechanisms and are lighter weight and lower strength.

Lights-Out Manufacturing

The concept of collaborative robotics has helped companies more flexibly integrate robotics into their processes, allowing humans to complete the last-mile tasks. As robots have become more affordable than ever, cost reductions can be made by automating more and more processes in factories and warehouses. For some, removing the human from the processes altogether is the ultimate goal.

A popular conceptual goal in manufacturing is to work toward **lights-out manufacturing**. The idea is that the factory is fully autonomous and can operate at full clip even with the lights out. Some factories have even achieved this goal. There are efficiencies that also come along with building a factory like this. The location no longer needs to be based on the availability of a large-enough work force, but solely around trucking logistics to deliver that product from the factory location.

Summary

While pop culture has most people fantasizing over humanoid robots that talk, walk, and think like humans, the robots making the largest impact in the fashion industry have little in common with these portrayals. Industrial robots, cartesian robots, and collaborative robots make up a large portion.

There is a growing presence of robotics in the fashion industry, particularly in manufacturing and warehousing settings. As robots are developed to handle increasingly complex and sewing-specific tasks, the fashion industry will be confronted with new challenges of ethical automation, designing for robotic automation, and reshoring production.

Terminology from This Chapter

Actuators—The "movers" in a mechanical system. In the systems described in this chapter, they are the component that allows the machine to move, given a control signal. They include things like lights and speakers—anything that transforms a signal into something that happens in the real world.

Articulated robots—Can be industrial, legged, or others types of robots that have joints, often powered by electric motors, which give them a complex range of motion.

Automation—The use of equipment or machines to automatically complete processes.

Bipedal—To walk on two legs, usually in reference to animal locomotion.

Cartesian robot—A robot that is limited by x, y, and z motion. They're also sometimes referred to as *linear robots* or *gantry robots* because of their visual resemblance to gantry cranes. Many CNC machines and 3D printers follow this type of architecture. See also *gantry robot.*

Collaborative robotics—Robots that can safely work alongside humans. The safety required is achieved through tactics such as sensing, speed, and power and force limiting.

Control system—The brains of the robot. The control system is where sensing occurs and decisions about actuation are made in response.

Degrees of freedom—The number of directions a device or robot can move in. The range of motion can have a large impact on which tasks the machine can carry out. In a human body, the shoulder has three3 degrees of freedom: pitch (up and down), yaw (left and right), and roll (rotation).

End effectors—In a robotic arm, these are analogous to hands. They are responsible for much of the dexterity of articulated robots.

Fembot—A robot that looks like a female that exists solely or primarily as a sexualized character or toy.

Gantry robot—See *cartesian robot.*

Industrial robots—Come in multiple shapes and sizes, many of which include manipulator arms or gantries. They have been historically used in industries dealing with rigid materials (for example, metals and plastics) in applications including automotive, warehousing, and more.

Lights-out manufacturing—The idea of automating every process in a factory so that no human is needed to keep the system in motion.

Manipulator arm—The arm of an articulated robot. See also *articulated robot.*

Payload capacity—How much weight a machine can carry.

Picking and packing—A commonly used term for the process of locating items to ship in a warehouse and packing them into a box for customers as part of fulfillment.

Power supply—The source of electrical power that enables the operation of a machine. Typically, this device also provides current conversion to provide the correct voltage, current, and frequency to the machine.

Reshoring—Bringing domestic manufacturing back to a country. This is the opposite of offshoring, which is the process of manufacturing in countries overseas, where labor is cheaper.

SoftWear Automation—A corporation based in Atlanta, Georgia, focused on robotic automation for sewing soft goods. The company began as a research initiative at Georgia Tech. After seven years of research, the company spun out to begin providing manufacturing work-lines for sewn goods in home goods, footwear, apparel, and automotive.

Uncanny valley—A term coined to capture the unsettling nature of machines that look like humans. The idea is that robots that have a human likeness, but are apparently not human, can elicit a feeling of revulsion from humans. The hypothesis is that the more unmistakably human a robot looks, the greater the emotional response from humans. In order to get to that point, the likeness needs to pass through this threshold to overcome the creepiness.

Thank you to Palaniswamy Rajan, chairman and chief executive officer at SoftWear Automation for answering questions about sewing and robotics for this chapter.
