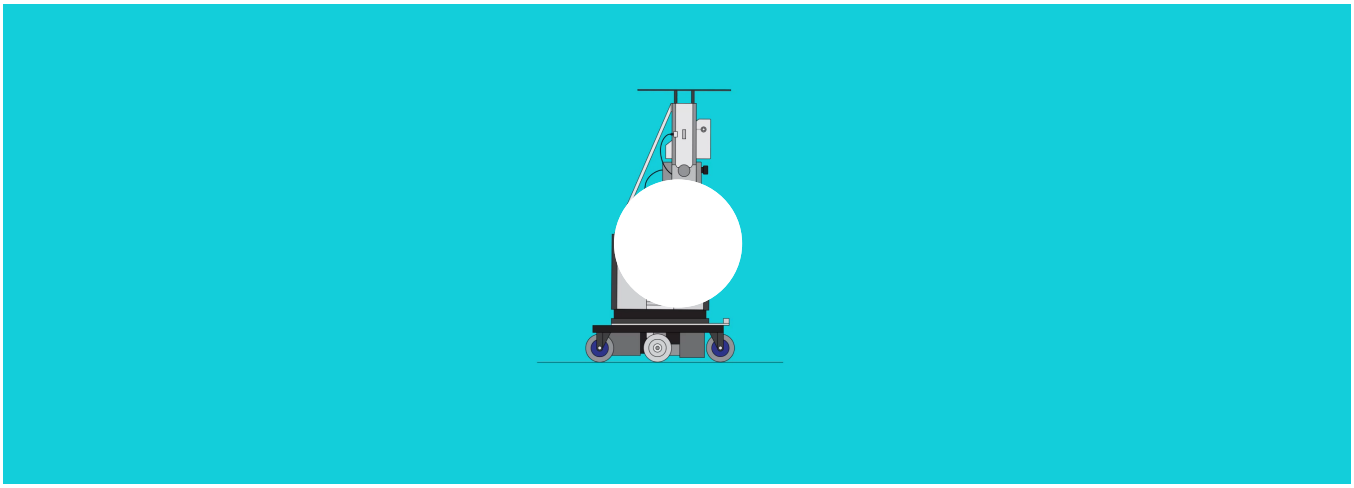
The WIRED Guide to Robots

Everything you wanted to know about soft, hard, and nonmurderous automatons.

BY Matt Simon



Radio

Modern robots are not unlike toddlers: It's hilarious to watch them fall over, but deep down we know that if we laugh too hard, they might develop a complex and grow up to start World War III. None of humanity's creations inspires such a confusing mix of awe, admiration, and fear: We want robots to make our lives easier and safer, yet we can't quite bring

ourselves to trust them. We're crafting them in our own image, yet we are terrified they'll supplant us.

But that hesitation is no obstacle to the booming field of robotics. Robots have finally grown smart enough and physically capable enough to make their way out of factories and labs to walk and roll and even leap among us. The machines have arrived.

You may be worried a robot is going to steal your job, and we get that. This is capitalism, after all, and automation is inevitable. But you may be more likely to work *alongside* a robot in the near future than have one replace you. And even better news: You're more likely to make friends with a robot than have one murder you. Hooray for the future!

The History of Robots

The definition of "robot" has been confusing from the very beginning. The word first appeared in 1921, in Karel Capek's play *R.U.R.*, or Rossum's Universal Robots. "Robot" comes from the Czech for "forced labor." These robots were robots more in spirit than form, though. They looked like humans, and instead of being made of metal, they were made of chemical batter. The robots were far more efficient than their human counterparts, and also way more murder-y—they ended up going on a killing spree.

R.U.R. would establish the trope of the Not-to-Be-Trusted Machine (e.g., *Terminator*, *The Stepford Wives*, *Blade Runner*, etc.) that continues to this day—which is not to say pop culture hasn't embraced friendlier robots. Think Rosie from *The Jetsons*. (Ornery, sure, but certainly not homicidal.) And it doesn't get much family-friendlier than Robin Williams as *Bicentennial Man*.

The real-world definition of "robot" is just as slippery as those fictional depictions. Ask 10 roboticists and you'll get 10 answers. But they do agree on some general guidelines: A robot is an intelligent, physically embodied

machine. A robot can perform tasks autonomously. And a robot can sense and manipulate its environment.

Robo-cabulary

Human-robot interaction

A field of robotics that studies the relationship between people and machines. For example, a self-driving car could see a stop sign and hit the brakes at the last minute, but that would terrify pedestrians and passengers alike. By studying human-robot interaction, roboticists can shape a world in which people and machines get along without breaking each other.

Singularity

The hypothetical point where the machines grow so advanced that humans are forced into a societal and existential crisis.

Multiplicity

The idea that robots and AI won't supplant humans, but complement them.

Actuator

Typically, a combination of an electric motor and a gearbox. Actuators are what power most robots.

Soft robotics

A field of robotics that foregoes traditional materials and motors in favor of generally softer materials and

Think of a simple drone that you pilot around. That's no robot. But give a drone the power to take off and land on its own and sense objects and suddenly it's a lot more robot-ish. It's the intelligence and sensing and autonomy that's key.

But it wasn't until the 1960s that a company built something that started meeting those guidelines. That's when SRI International in Silicon Valley developed Shakey, the first truly mobile and perceptive robot. This tower on wheels was well-named—awkward, slow, twitchy. Equipped with a camera and bump sensors, Shakey could navigate a complex environment. It wasn't a particularly confident-looking machine, but it was the beginning of the robotic revolution.

Around the time Shakey was trembling about, robot arms were beginning to transform manufacturing. The first among them was Unimate, which welded auto bodies. Today, its descendants rule car factories, performing tedious, dangerous tasks with far more precision and speed than any human could muster. Even though they're stuck in place, they still very much fit our definition of a robot—they're intelligent machines that sense and manipulate their environment.

pumping air or oil to move its parts.

Lidar

Lidar, or light detection and ranging, is a system that blasts a robot's surroundings with lasers to build a 3-D map. This is pivotal both for self-driving cars and for service robots that need to work with humans without running them down.

Humanoid

The classical sci-fi robot. This is perhaps the most challenging form of robot to engineer, on account of it being both technically difficult and energetically costly to walk and balance on two legs. But humanoids may hold promise in rescue operations, where they'd be able to better navigate an environment designed for humans, like a nuclear reactor.

Robots, though, remained largely confined to factories and labs, where they either rolled about or were stuck in place lifting objects. Then, in the mid-1980s Honda started up a humanoid robotics program. It developed P3, which could walk pretty darn good and also wave and shake hands, much to the delight of a roomful of suits. The work would culminate in Asimo, the famed biped, which once tried to take out President Obama with a well-kicked soccer ball. (OK, perhaps it was more innocent than that.)

Today, advanced robots are popping up *everywhere*. For that you can thank three technologies in particular: sensors, actuators, and AI.

So, sensors. Machines that roll on sidewalks to deliver falafel can only navigate our world thanks in large part to the 2004 Darpa Grand Challenge, in which teams of roboticists cobbled together self-driving cars to race through the desert. Their secret? Lidar, which spews lasers to build a 3-D map of the world. The ensuing private-sector race to develop self-driving cars has dramatically driven down the price of lidar, to the point that engineers can create perceptive robots on the (relative) cheap.

Lidar is often combined with something called machine vision—2-D or 3-D cameras that allow the robot to build an even better picture of its world. You know how Facebook automatically recognizes your mug and tags you in pictures? Same principle with robots. Fancy algorithms allow them to pick out certain landmarks or objects.

Sensors are what keep robots from running us down. They're why a robot

mule of sorts can keep an eye on you, following you and schlepping your stuff around; machine vision also allows robots to scan cherry trees to determine where best to shake them , helping fill massive labor gaps in agriculture.

Within each of these robots is the next secret ingredient: the actuator, which is a fancy word for the combo electric motor and gearbox that you'll find in a robot's joint. It's this actuator that determines how strong a robot is and how smoothly or not smoothly it moves. Without actuators, robots would crumple like rag dolls. Even relatively simple robots like Roombas owe their existence to actuators. Self-driving cars, too, are loaded with the things.

Actuators are great for powering massive robot arms on a car assembly line, but a newish field, known as soft robotics, is devoted to creating actuators that operate on a whole new level. Unlike mule robots, soft robots are generally squishy, and use air or oil to get themselves moving. So for instance, one particular kind of robot muscle uses electrodes to squeeze a pouch of oil, expanding and contracting to tug on weights. Unlike with bulky traditional actuators, you could stack a bunch of these to magnify the strength: A robot named Kengoro, for instance, moves with 116 actuators that tug on cables, allowing the machine to do unsettlingly human maneuvers like pushups. It's a far more natural-looking form of movement than what you'd get with traditional electric motors housed in the joints.

And then there's Boston Dynamics, which created the Atlas humanoid robot for the Darpa Robotics Challenge in 2013. At first, university robotics research teams struggled to get the machine to tackle the basic tasks of the original 2013 challenge and the finals round in 2015, like turning valves and opening doors. But Boston Dynamics has since that time turned Atlas into a marvel that can do backflips, far outpacing other bipeds that still have a hard time walking. (Unlike the Terminator, though, it does not pack

heat.) Boston Dynamics is also working on a quadruped robot called SpotMini, which can recover in unsettling fashion when humans kick or tug on it. That kind of stability will be key if we want to build a world where we don't spend all our time helping robots out of jams. And it's all thanks to the humble actuator.

At the same time that robots like Atlas and SpotMini are getting more physically robust, they're getting smarter, thanks to AI. Robotics seems to be reaching an inflection point, where processing power and artificial intelligence are combining to truly ensmarten the machines. And for the machines, just as in humans, the senses and intelligence are inseparable—if you pick up a fake apple and don't realize it's plastic before shoving it in your mouth, you're not very smart. This is a fascinating frontier in robotics (replicating the sense of touch, not eating fake apples). A company called SynTouch, for instance, has developed robotic fingertips that can pick up a range of sensations, from temperature to coarseness.

As sensors are getting cheaper, the superpowered processors required for AI are doing the same. Thanks to advances in gaming and VR—graphics processing units, or GPUs, are helping mobile robots to perform complex computations right onboard the machine, as opposed to in the cloud, which means they can still operate if they lose their connection. This is particularly important for powering that machine vision, which allows a robot like Kuri to recognize your face. To help you, by the way, not hunt you or anything.

Ideally, that is.

The Future of Robots

Increasingly sophisticated machines may populate our world, but for robots to be really useful, they'll have to become more self-sufficient. After all, it would be impossible to program a home robot with the instructions for gripping each and every object it ever might encounter. You want it to

learn on its own, which is where advances in artificial intelligence come in.

Take Brett the robot. In a UC Berkeley lab, the humanoid has taught itself to conquer one of those children's puzzles where you cram pegs into different shaped holes. It did so by trial and error through a process called reinforcement learning. No one told it *how* to get a square peg into a square hole, just that it *needed* to. So by making random movements and getting a digital reward (basically, *yes, do that kind of thing again*) each time it got closer to success, Brett learned something new on its own. The process is super slow, sure, but with time roboticists will hone the machines' ability to teach themselves novel skills in novel environments, which is pivotal if we don't want to get stuck babysitting them.

13 Robots, Real and Imagined

1/13**Pygmalion (Ancient Greece)** The start of it all. In Greek mythology, Pygmalion sculpted a female figure out of ivory, and found himself falling for her. He kissed her, and she felt warm, which is weird for ivory. Aphrodite transformed the statue into a real live human woman so Pygmalion could marry her. Thus comes an intelligent humanoid machine into being.Heritage Images/Getty Images

2/13**Rossum's Universal Robots (1921)** Karel Capek's 1921 play *Rossum's Universal Robots* introduces the word "robot" into the lexicon, though these artificial laborers were made of chemical batter, not metal. They were also more murderous than most robots, helping solidify the "killer machines" trope.Pictorial Press/Alamy

6/13**C-3PO and R2-D2 (1977)** The greatest robot duo of all time. That is all.AF/Alamy

1/13**Pygmalion (Ancient Greece)** The start of it all. In Greek mythology, Pygmalion sculpted a female figure out of ivory, and found himself falling for her. He kissed her, and she felt warm, which is weird for ivory. Aphrodite transformed the statue into a real live human woman so Pygmalion could marry her. Thus comes an intelligent humanoid machine into being.Heritage Images/Getty Images

Speaking of. For the near future we are going to have to babysit the robots. As advanced as they've become, they still struggle to navigate our world. They plunge into fountains, for instance. So the solution, at least for the short term, is to set up call centers where robots can phone humans to help them out in a pinch. For example, Tug the hospital robot can call for help if

it's roaming the halls at night and there's no human around to move a cart blocking its path. The operator would them teleoperate the robot around the obstruction.

The rapidly developing relationship between humans and robots is so complex that it has spawned its own field, known as human-robot interaction. The overarching challenge is this: It's easy enough to adapt robots to get along with humans—make them soft and give them a sense of touch—but it's another issue entirely to train humans to get along with the machines. With Tug the hospital robot, for example, doctors and nurses learn to treat it like a grandparent—get the hell out of its way and help it get unstuck if you have to. We also have to manage our expectations: Robots like Atlas may *seem* advanced, but they're far from the autonomous wonders you might think.

What humanity has done is essentially invented a new species, and now we're maybe having a little buyers' remorse. Namely, what if the robots steal all our jobs? Not even white-collar workers are safe from hyper-intelligent AI, after all.

A lot of smart people are thinking about the singularity, when the machines grow advanced enough to make humanity obsolete. That will result in a massive societal realignment and species-wide existential crisis. What will we do if we no longer have to work? How does income inequality look anything other than exponentially more dire as industries replace people with machines?

These seem like far-out problems, but now is the time to start pondering them. Which you might consider an upside to the killer-robot narrative that Hollywood has fed us all these years: The machines may be limited at the moment, but we as a society need to think seriously about how much power we want to cede. Take San Francisco, for instance, which is exploring the idea of a robot tax, which would force companies to pay up when they displace human workers.

I can't sit here and promise you that the robots won't one day turn us all into batteries, but the more realistic scenario is that, unlike in the world of *R.U.R.*, humans and robots are poised to live in harmony—because it's already happening. This is the idea of multiplicity, that you're more likely to work *alongside* a robot than be replaced by one. If your car has adaptive cruise control, you're already doing this, letting the robot handle the boring highway work while you take over for the complexity of city driving.

The machines promise to change virtually every aspect of human life, from health care to transportation to work. Should they help us drive? Absolutely. (They will, though, have to make the decision to sometimes kill, but the benefits of precision driving far outweigh the risks.) Should they replace nurses and cops? Maybe not—certain jobs may always require a human touch.

One thing is abundantly clear: The machines have arrived. Now we have to figure out how to handle the responsibility of having invented a whole new species.

Learn more

- **Forget the Robot Singularity Apocalypse. Let's Talk About the Multiplicity**
  We don't want you to worry, honestly. If a robot takes your job, it'll be a long, long way off. More likely, you'll be working *with* robots. It's called the multiplicity, and it actually sounds rather fun.

- **The Tale of the Painting Robot That Didn't Steal Anyone's Job**
  Want proof? Visit a painting company that hired robots not to replace workers, but to make them more efficient and the firm more competitive.

- **2017 Was the Year the Robots Really, Truly Arrived**

If you've been noticing lately that there seem to be a whole lot more robots around, it's not just you. A number of factors, including better algorithms and burlier processors, have come together to help robots finally navigate our world. And it all happened in 2017.

- **Robots Are Fueling the Quiet Ascendance of the Electric Motor**
  For something born over a century ago, the electric motor really hasn't fully extended its wings. The problem? Fossil fuels are just too easy, and for the time being, cheap. But now, it's actually robots, with their actuators, that are fueling the secret ascendence of the electric motor.

- **Are We Ready for Intimacy With Androids?**
  You're thinking it, so we may as well talk about it: Increasingly advanced and realistic androids are going to be hard not to fall in love with.

- **The Genesis of Kuri, the Friendly Home Robot**
  On the other hand, cute little companion robots aren't meant for you to fall in love with. They're meant for ... something or other. Hard to tell at the moment.

This guide was last updated on May 15, 2018.

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