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Technology is changing the nature of the jobs we do and the way we do them. What does that mean for the future of work?



The Big Question

Work in Transition

Digital technologies are changing the nature of the jobs we do. What does that mean for the future of work?

● About five years ago, machine learning reached a point where software could, with guidance from senior lawyers, effectively take over the time-intensive task of legal discovery, in which one party in a lawsuit combs through its documents to determine what it must show to the other side before trial.

This is a job that junior lawyers, paralegals, or—increasingly—less expensive contract lawyers had traditionally done, and some fretted that the change might be just the first step in the computerization of the law. But while machine learning does well with structured tasks like searching for relevant words, handling documents similar to others already identified, and even reconstructing simple summaries of a baseball game, it is far less adept at constructing something like a legal memo, where persuasiveness can rely on developing novel arguments, explains economist Frank Levy, an MIT professor emeritus who, with Dana Remus, a professor at the University of North Carolina School of Law, is researching computers' impact on the practice of law.

"There's much less structure in a legal memo, which is trying to figure out a strategic approach to an argument," says Levy, who coauthored (with Harvard professor Richard Murnane) an influential book, *The New Division of Labor*, about how computers are changing employment and the job market. Adds Levy: "You are putting a premium on innovation."

It's likely that work done by humans will increasingly involve innovative thinking, flexibility, creativity, and social skills, the things machines don't do well. In a recent study on automation from the University of Oxford, researchers tried

to quantify how likely jobs are to be computerized by evaluating how much creativity, social intelligence, and dexterity they involve. Choreographers, elementary school teachers, and psychiatric social workers are probably safe, according to that analysis, while telemarketers and tax preparers are more likely to be replaced.

Most professions won't go the way of the telemarketer, but the work involved is likely to migrate toward the tasks humans are uniquely skilled at, with automation taking over tasks that are rules-based and predictable.

How jobs are evolving in this new model of work is the big question this report seeks to examine.

In addition to affecting the type of work we do, digital and mobile technologies are changing how we do it, where we do it (at home or remotely), and who our competition is. At Upwork, a platform that connects freelancers with jobs, 50 percent of corporate customers are based in the United States, but only 20 percent of the workers are. Opening up a global talent competition could make it harder to earn high wages.

A growing number of platforms like Upwork, TaskRabbit, Uber, Airbnb, and others that connect freelancers to clients are creating a new type of labor market, something consultant Sangeet Paul Choudary calls "networked work." In this world, workers are responsible for their own development and assume many of the risks employers once bore. They depend on the platform for business, but they also have the ability to develop a reputation based on client satisfaction.

This networked model is disruptive enough to have led to riots in Tianjin, China, where taxi drivers are fighting the arrival of Uber and the bite it has taken out of their income. The people who drive for Uber are largely part-timers looking to make a little extra money. Uber customers in China take nearly one million rides a day, the company says, and management is investing more than \$1.1 billion to expand into 100 more cities this year. The job of driving cars has not gone away, but the way that work is done is changing, and the transition is not painless.

Tim O'Reilly, CEO of O'Reilly Media, has recently been writing about how tech-

Hot Jobs

Some of the jobs expected to grow fastest in the U.S. over the next seven years

	Number of jobs, 2012	Median pay, 2012	Rate of growth, 2012-2022**	Likelihood of being automated
INDUSTRIAL-ORGANIZATIONAL PSYCHOLOGIST	160,200	\$69,280	53%	low
DIAGNOSTIC MEDICAL SONOGRAPHER	110,400	\$60,350	46%	medium
GENETIC COUNSELOR	2,100	\$56,800	41%	unavailable
PHYSICIAN'S ASSISTANT	86,700	\$90,930	38%	low
INFORMATION SECURITY ANALYST	75,100	\$86,170	37%	low
OCCUPATIONAL THERAPY AIDE	38,600	\$48,940	36%	low
MEDICAL SECRETARY	3,947,100*	\$35,330*	36%	high
PHYSICAL THERAPIST	204,200	\$79,860	36%	low

DATA: BUREAU OF LABOR STATISTICS; CARL BENEDIKT FREY AND MICHAEL A. OSBORNE, UNIVERSITY OF OXFORD. *INCLUDES ALL TYPES OF SECRETARIES. **EXPECTED.

nology can both create new types of jobs and improve the quality of work. Mobile and sensor technologies could support health workers and help elderly people stay in their homes, for example, while machine learning could help doctors make decisions.

Some jobs will surely be automated out of existence, but technology has the potential to create new jobs as well.

—*Nanette Byrnes*

Data Analysis

Where the Tech Jobs Are

Expanding supplies of data and cheap processing power will drive demand for IT specialists in a broad range of fields.

● Jobs in science, technology, engineering, and math (STEM) overpopulate the U.S. Labor Department list of occupations expected to grow the most through 2022: among the 580 occupations the department tracks, they make up 14 of the 35 fastest-growing.

Fewer than half the available jobs in categories like data science and programming are in technology industries as traditionally defined, according to the job-hunting site Glassdoor. The rest are in a range of fields that are benefiting from the falling cost of data storage and the increase in processing speeds that

for almost 13,000 software engineers, 1,568 data scientists, 1,691 programmer analysts, and 4,033 database administrators. (Overall, the U.S. economy is adding about 230,000 jobs a month.) Depending on the job title, 60 percent to 75 percent were at non-IT companies, Chamberlain says.

Regulatory changes have also increased the focus on data. The Dodd-Frank law imposes new reporting requirements on banks. The Affordable Care Act is driving hospitals and independent doctors toward quality management and measurement programs that depend on computing. With the population aging, the U.S. government predicts that 62 percent of new STEM jobs added through 2022 will be in health care. Partners HealthCare in Boston has hired more than 600 IT professionals to implement its new electronic medical records system.

In energy, another increasingly data-intensive field, predictive analytics software run on a massive scale recommends where to drill and how much water to use in each well. Even fields that were once the sole domain of humanities majors, like advertising, are hunting for technologists today. At the Austin ad agency T3, CEO Gay Gaddis is currently looking for user-experience designers, Android developers, and data analysts.

Over the next decade, the Bureau of Labor Statistics projects, the ranks of genetic counselors, market research analysts, and information security analysts will grow by 30 percent or more. Jobs

“Across STEM, very few fields are declining,” says Bureau of Labor Statistics economist Michael Wolf.

Salaries and demand are both rising fast. A UCLA analysis of 2013 data published this June contended that the average tech worker in San Mateo County, which

.....
13,000
.....

Number of recent listings for software engineers on Glassdoor

includes Facebook’s Menlo Park headquarters, is making more than \$300,000. The unemployment rate in San Francisco is 3.5 percent. STEM jobs today pay almost double the average wage in the economy as a whole, says economist Sophia Koropecyk, a managing director at Moody’s Analytics: “The high compensation of these jobs gives them an outsize role in promoting economic growth.” —*Tim Mullaney*

Venture Capital

On the Edge of Automation

Five hundred years from now, says venture capitalist Steve Jurvetson, less than 10 percent of people on the planet will be doing paid work. And next year?

● As a founding partner at the venture capital firm Draper Fisher Jurvetson and a board member at SpaceX and Tesla Motors, Steve Jurvetson spends a lot of time thinking about the future, often the distant future. One of Elon Musk’s biggest backers—Jurvetson boasts that he owns the first Tesla production Model S—he was also a founding investor in Hotmail, the precursor to Microsoft Outlook, and sits on the board of Craig Venter’s Synthetic Genomics, the constructor of the first synthetic cell.

His firm claims to have funded companies that have created more than 20,000 jobs in the past five years, and to have

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Job growth in fields like computer-directed stock trading and electronic medical records is being driven by expanding pools of data that can be crunched economically.
.....

allows data to be crunched economically, says Andrew Chamberlain, Glassdoor’s chief economist—fields like computer-directed stock trading, electronic medical records, and even more mature industrial sectors. On Glassdoor, which aggregates job postings from across the Internet, there were recently listings

in civil and petroleum engineering will grow at the same 20 to 29 percent rate as systems analysts, and health-care reform, which seeks to have more work done by workers who make less money than doctors, will help increase employment of physician’s assistants and nurse practitioners by 30 percent or more.

brought nearly two dozen companies to \$1 billion in value before exiting. Jurvetson spoke to Business Reports senior editor Nanette Byrnes about why he thinks 90 percent of people will be unemployed in 500 years and how we might transition to that sharply different future.

Are today's new digital technologies destroying or creating jobs?

I absolutely believe in the near to medium term there is going to be net job creation, as there always has been. Think of all the Uber jobs. The opportunity is not yet fully tapped to, in a sense, distribute [over the Internet] the service economy. The service economy is bigger than the goods economy, so the online equivalent should be even bigger and more powerful than the online marketplace for physical goods.

"Five hundred years from now, everyone is going to be involved in some kind of information or entertainment ... There will be no farmers, there will be no people working in manufacturing."

Many of these new jobs, including those at Uber, are taking shape on what you call the "edge of automation." Do you fear that these jobs might quickly disappear as technology keeps evolving?

Everything about Uber has been automated except for the driver. The billing, the fetching—every part of it is a modern, information-centric company. Interestingly, what that means is as soon as automated vehicles arrive, that driver is easily removed. You don't have to restructure any part of that business.

What you're farming out to humans today are those things that computers just barely can't do. We know from Moore's Law and improvements in computing that in two or three years [much of this] work will be automated.

If a startup or new business venture has created a job that involves human labor, it probably has done so in a way that is pretty marginal. Whether you're a technology enthusiast or a detractor, the rate at which this will shift is probably going to be unprecedented. There will be massive dislocation.

Which jobs will survive?

In the long run, 500 years from now, everyone is going to be involved in some kind of information or entertainment. Nobody on the planet in 500 years will do a physically repetitive thing for a living. There will be no farmers, there will be no people working in manufacturing. To me it is an impossibility that people would do that. People might do it for fun. You might have an organic garden in your backyard because you love it. Five hundred years from now I don't know if even 10 percent of people on the planet have a job in the sense of being paid to do something.

It's hard to imagine what that life would be like.

It pretty much will be what life was like for most of human history—just without the

gruesome servitude. The concept of a "job" is pretty recent. If you go back a few hundred years, everyone was either a slave or a serf, or living off slave or serf labor to pursue science or philosophy or art. We'll live off the production of robots, free to be the next Aristotle or Plato or Newton. Unless we're miserable without doing busy work.

Is there some way, some government policies or strategies, to minimize the pain of such a dramatic shift?

I don't think that anyone in Washington is going to get their head around this and make meaningful change. No politician has a 50-year horizon. I see zero chance that long-term thinking will govern policy.

The knock on Silicon Valley today is that it's not taking on big problems either.

I do lament how many investors focus on all the short-term sugar buzz of some marginal improvement in something—nothing history books are ever going to be written about. In many cases these are quick and easy ways to make money. I do think there are more and more entrepre-

neurs all the time that think big. Those are the people we should be finding and funding. Most of them will fail, but the ones who succeed will change the world, and that is progress.

Data Analysis

The Measured Working Man

The technology that illuminates worker productivity and value also contributes to wage inequality, Tyler Cowen argues.

● Discussions of income inequality typically focus on how information technology raises the return to skilled labor, or on the rise of global trade, or perhaps on the way that politics skews power toward the rich and well-connected. But there's another fundamental driver of income inequality: the improved measurement of worker performance. As we get better at measuring who produces what, the pay gap between those who make more and those who make less grows.

Consider journalism. In the "good old days," no one knew how many people were reading an article like this one, or an individual columnist. Today a digital media company knows exactly how many people are reading which articles for how long, and also whether they click through to other links. The exactness and the transparency offered by information technology allow us to measure value fairly precisely.

The result is that many journalists turn out to be not so valuable at all. Their wages fall or they lose their jobs, while the superstar journalists attract more Web traffic and become their own global brands. Some even start their own media companies, as did Nate Silver at FiveThirtyEight and Ezra Klein at Vox. In this case better measurement boosts income inequality more or less permanently.

In any organization or division many colleagues do good work, but only so many would be truly difficult to replace.

And those are the people who, with better measurement of economic value, receive higher salaries and bonuses.

Imagine a situation where a group of workers produces some output collectively. The tendency is to resort to equal pay scales, perhaps with some inequality built in for seniority and other highly visible characteristics, such as working overtime. Relatively equal pay structures help build group solidarity, and in the meantime the superior producers cannot easily demonstrate their worth to other potential employers because no publicly observable measurements capture that added value.

But as information about productivity improves, the better workers demand more and can get it; in fact, bosses will want to offer more to preempt them from leaving. Workers also stop thinking of themselves as bringing the same value to the table, and that can make inegalitarian pay structures less damaging to morale and thus more attractive.

One unfortunate possibility, or shall I say likelihood, is that some workers may not produce much of anything at all. They may be major shirkers, or perhaps they are smart and talented workers who nonetheless are poison for workplace morale. Their office scheming takes away more than their labor adds. These “zero marginal product” workers, as I have labeled them elsewhere, may have a hard time holding down a job. In the modern world it is harder for them to hide behind the labor of others.

Insofar as workers type at a computer, everything they do is logged, recorded, and measured. Surveillance of workers continues to increase, and statistical analysis of large data sets makes it increasingly easy to eval-

uate individual productivity, even if the employer has a fairly noisy data set about what is going on in the workplace.

This analysis, if only in crude forms, starts when workers are applying for a job. A significant percentage of bosses in America look up an employee’s credit score before making a hiring decision. Some employers are even using performance in online video games to evaluate individual talent. There are also Facebook, Twitter, LinkedIn, and numerous other social-media outlets, all of which do give us some clues about character, effort, and the quality of a person’s social connections. It’s not hard to imagine a future where an individual’s eBay and Uber ratings, among other pieces of information, are up for sale in the marketplace. The more reliable job candidates might dis-

close such information voluntarily. Over time schools may offer more information about their students than just GPAs and letters of recommendation, as statistical analysis improves in its ability to assess their potential.

Looking further ahead, and more speculatively, employers might request genetic information from workers. Anyone who doesn’t want to turn it over might be seen as having something to hide, and thus this information will spread even if you may feel that our society doesn’t want to tolerate genetic discrimination. Or perhaps the information can be lifted from a doorknob or from a cup of coffee during an interview visit. It’s hard to imagine that this valuable source of information will stay confidential forever, given that most databases have proved hackable.

This explanation for growing inequality has some potentially distressing features, but also some upside.

The upside, quite simply, is that measuring value tends to boost productivity, as has been the case since the very beginning of management science. We’re simply able to do it much better now, and so employers can assign the most productive workers to the most suitable tasks. Workplace incentives can also be more closely geared to the actual production of value for the enterprise.

The downsides are several. Individuals don’t in fact enjoy being evaluated all the time, especially when the results are not always stellar: for most people, one piece of negative feedback outweighs five pieces of positive feedback. To the extent that measurement raises income inequality, perhaps it makes relations among the workers tenser and less friendly. Life under a meritocracy can be a little tough, unfriendly, and discouraging, especially for



those whose morale is easily damaged. Privacy in this world will be harder to come by, and perhaps “second chances” will be more difficult to find, given the permanence of electronic data. We may end up favoring “goody two-shoes” personality types who were on the straight and narrow from their earliest years and disfavor those who rebelled at young ages, even if those people might end up being more creative later on.

That said, measurement of worker value isn’t going away anytime soon. The real question is not whether we want it or not, but how to make it better rather than worse. Ideally we’d have a system where individuals can correct measurement errors in their records to prevent injustice and preserve accuracy. We’d also like a system where individuals are not tracked and segmented too early, where outsiders and immigrants receive a fair hearing, where risk taking is rewarded rather than punished, and where some degree of privacy, including privacy in the workplace, remains.

Obviously, that is a tall order.

I wonder, by the way, if *MIT Technology Review* will tell me how many people clicked on this article. —Tyler Cowen

The author is a professor of economics at George Mason University.

Mobile Apps

Uber’s Bumpy Ride in China

Chinese Uber drivers are making a million trips a day, pleasing consumers but threatening traditional taxi drivers.

● Mornings at 5, Mr. Dong, a manager at a livestock farming company in Tianjin, logs in to his Uber account. Before he heads off for work at 7, he can make three to four trips around the city center in his Buick. After he leaves his office at 6 p.m., he continues driving until 9 p.m. On weekend mornings, he’s in such high demand

that he can complete as many as 10 trips before noon.

“Right now a lot of people are using these services,” says Mr. Dong, 38, who gave only his last name to avoid jeopardizing his full-time job. On top of covering his monthly gas money of about 1,000 yuan (\$156), he can earn between 800 yuan (\$125) and 1,000 yuan every month by driving for Uber.

In China, private Uber drivers are making almost a million trips per day, according to the CEO of Uber. Less than

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Uber is in a legal gray area. Speculation has increased that regulation of online taxi reservations may be coming.
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two years after its launch here, Uber has developed a fierce rivalry with the home-grown Didi Kuaidi, which reports that its daily private-car requests have tripled to three million since May, and engendered resentment among traditional taxi drivers.

Chinese cities in some ways seem ripe for a technology-driven transportation overhaul. The roads are jammed. According to government figures, there were almost 126 million private vehicles in China at the end of 2014, a 15.5 percent increase from the previous year. The 2014 TomTom Traffic Index shows that a third of the 50 most congested cities in the world are in China. Other commuting options are painful, too—during rush hours a rider in the Beijing subway has to wait for several loaded trains to pass before squeezing in.

The Chinese State Council has identified transportation as one of the traditional industries whose efficiency could be improved by online platforms, but Uber remains in a legal gray area. Its drivers are considered private car operators and do not pay all the registration fees, value-added tax, and income taxes traditional cabbies do. Uber drivers say they often avoid places where there are a lot of police officers, such as airports and train stations. If they are caught, the fines can be as high as 10,000 yuan (\$1,564). Recently speculation has increased that online taxi reservations will become a regulated business.

Uber’s not waiting. With the newly set up UberChina, the ride-hailing service plans to expand into 100 Chinese cities, at least half with a population over five million, in the next year. (It currently operates in 11 cities, including Tianjin, with an average population of 14 million.) The company also plans to invest more than seven billion yuan (\$1.1 billion) in China in 2015.

Drivers of China’s 1.37 million traditional taxis are already reacting. In May, dozens of cabbies blocked the roads

around the Olympic stadium in Tianjin with their cars and lured private-car drivers to the area using ride-hailing apps. As soon as they arrived, the two groups started fighting.

“I’m a bit dispirited,” says Lu Lifang, 48, a traditional taxi driver. “If the government doesn’t regulate the private cars, my profession will disappear sooner or later.” She and her fellow cabbies also complain about dwindling income. Wang Hongyong, 47, says he earns about 150 yuan (\$23) less per day now than he did in 2014. “I’m also more tired,” he says. “I don’t rest in between.”

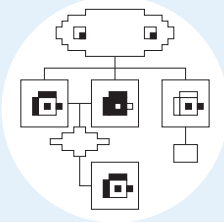
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1,000,000

Number of trips being made daily by
Uber drivers in China
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Driving is not a livelihood for most Uber drivers. Most, like Mr. Dong, drive for extra cash. Xing Gao, who works at an insurance company in Tianjin, hasn’t picked up any calls on his Uber app since June because the company has dropped to nearly zero the subsidy it was paying him for each completed trip. In 2014, he had a guaranteed 30 yuan (\$5) subsidy per trip. “They want to test the bottom line of drivers,” says Xing, 32, “just to see how much lower they can go before you quit.” —Yiting Sun

HIRED AND FIRED BY ALGORITHM

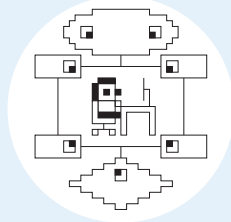
The cycle of how we find, keep, and lose jobs is increasingly affected by algorithms. Here are some of the data-mining companies aiming to take the “human” out of “human resources.” By Julia Sklar



Step 1

Finding job candidates

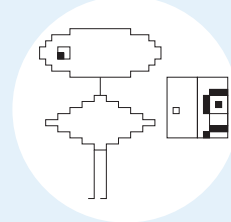
Seattle-based **Textio**, whose clients include Microsoft, evaluates job postings to predict if they’re likely to attract the right candidate. For example, phrases such as “top tier” and “mission critical” tend to turn female candidates off. San Francisco-based **Gild** sifts data from sites like LinkedIn and Github to tell customers such as Facebook and HBO when candidates might be open to a new post. **KF4D**, an algorithm from headhunter Korn Ferry, calculates the characteristics of an effective leader in a given industry and location, a model employers can then compare candidates against.



Step 2

Tracking employees

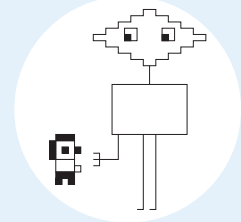
Following billions of dollars in fines for misconduct in recent years, many Wall Street firms have begun closely tracking workers. The goal: to both catch and forecast bad behavior. **J.P. Morgan** has designed a system to use data about things like whether individuals attend compliance classes to feed its predictive models of employee behavior, part of a \$730 million overhaul of its management system. Goldman Sachs and Credit Suisse are investors in **Digital Reasoning System**, which analyzes billions of employee e-mails, phone calls, and online chats to predict and prevent illegal behavior.



Step 3

Quitting

According to **Visier**, a workforce analytics group based in San Jose, California, unwanted employee turnover costs the average large company \$31 million a year. Visier uses two to three years’ worth of data from client companies like Yahoo, ConAgra, and Nissan to build predictive models that it says are up to eight times better than human intuition at forecasting which employees are at risk of quitting within three months. Each employee’s risk score is based on factors like age, salary, department, and time since last promotion. The company manages data for over two million employees.



Step 4

Finding the next job

Seattle-based **Anthology** (formerly known as Poachable) is like a dating app for the business world: employees looking for a change and businesses looking to hire each provide anonymous information about what they are looking for. A direct line of communication opens between users and businesses only if their interests match. Barely a year old, Anthology has clients that include Amazon, Facebook, IBM, and Netflix. Some 50,000 job seekers are using the app for free. Anthology has raised \$1.8 million in funding.

Tools

Aging Workers, New Technology

The number of workers over 65 is growing fast. Technologists see a big business in helping the aging workforce.

● The American tradition of retirement at age 65 is crumbling. As older workers stay on the job longer, challenges ranging from

eyestrain to aching joints become increasingly prevalent. In response, technologists and ergonomics experts are rethinking working conditions.

As recently as 1992, less than 3 percent of the American workforce consisted of people age 65 and over. Today that proportion has nearly doubled, according to the U.S. Bureau of Labor Statistics, and it’s expected to reach 8.3 percent by 2022. Most of these 13.5 million older workers will be between 65 and 74, but nearly 2.6 million will be 75 and over.

One reason for this demographic shift is improved longevity. American men who

reach 65 can expect to live another 17.9 years on average, the National Center for Health Statistics calculates, while women can count on 20.5 years. Both figures are up more than a third from the norms of the 1950s. With so much life still ahead, high-status workers may not want to be idle, while low-paid workers often find that meager savings won’t let them quit. At the same time, thanks to the service sector’s steady ascendancy over manufacturing, many jobs require less physical stamina.

While it’s easier to wield a stapler than a rivet gun at age 70, some aspects of office

life can still vex people beyond a certain age. “Many products are designed with younger users in mind,” says Sara Czaja, scientific director of the Center on Aging at the University of Miami. “Designers don’t always think about older people.”

Consider smartphones’ tiny screens. Office workers who frequently text or check their news feeds and e-mail may switch between near and far vision 100 or more times a day, say researchers at Germany’s Carl Zeiss Vision, a leading manufacturer of eyeglass lenses. That’s a particular strain for older workers with a diminished ability to focus on nearby objects, a condition that typically begins between ages 40 and 50 and then gets steadily worse.

To minimize digital eyestrain, Zeiss shifts the reading area in its progressive lenses higher and closer to the eyes, taking into account the position in which people hold their smartphones.

Another challenge: the eyes of 60-year-olds take in only about a third as much light as those of 20-year-olds, because their pupils are smaller and their lenses cloudier. That necessitates brighter office lighting, with as few shadows and dark spots as possible, says Ryan Anderson, director of product and portfolio strategy at Herman Miller, the office furniture maker based in Zeeland, Michigan. It’s not enough to blast more lumens onto people’s desktops; minimizing shad-

ows and dark zones is just as crucial. That has led to new types of overhead lighting fixtures that bounce most of their light off the ceiling for optimal dispersion, rather than aiming directly below.

Older workers also often need more back support, Anderson says, which creates problems if sustained use of laptops or tablets tempts people to lean forward at their desks. One Herman Miller solution: a desk with a sliding surface that can be drawn nearer to the user, making it possible to sit upright and rest against a chair back while using a mobile device at close range.

At Florida State University, Neil Charness, director of the Institute for Successful Longevity, has taken an interest in the challenges that using a computer mouse can present for older workers. “I’ve been studying aging for a long time,” he says, “and now, at age 67, I’ve become one of the people I study.” He is glad that many operating systems can be set to allow programs and documents to be activated by single-clicking; double-clicking can be harder for older users. He reduces his own need to scroll down with a mouse by turning his computer monitor sideways; eye movements tend to be easier for older adults than hand movements.

Microsoft has for years provided an online “Guide for Individuals with Age-Related Impairments,” showing older

workers how to create slower-moving pointers or magnified screen displays by adjusting their computer’s settings. Now Ai Squared, based in Manchester, Vermont, has developed software for people with macular degeneration, a condition predominantly affecting older people, in which a deteriorating retina causes vision loss in the center of the visual field. Its technology can transform display colors so that people who have trouble with black type on a white background might see their e-mail and Web pages as yellow type on a black background, which is often easier to read. “One gentleman uses our software to make everything purple on a pink background,” says Ai Squared marketing project manager Megan Long. “That’s what works best for him.”

For older workers who stand—rather than sit—on the job, specialized floor pads better balance the load on ankles, knees, and hips. These “anti-fatigue mats” have been common since the 1980s, but inventors keep refining the concept. One version, with arrays of hollow rubber cylinders fused in place under the mat’s surface to provide a mild springiness, was patented in 2009. Hospitals are major buyers. The average age of U.S. nurses climbed to 50 in 2013, according to the National Council of State Boards of Nursing, up from about 47 in 2004.

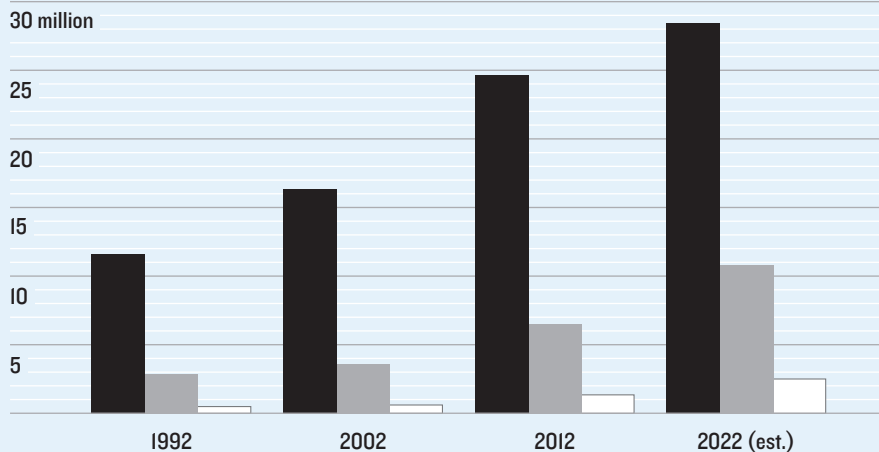
A broad array of technologies that are being developed to help those with disabilities could also end up helping other people work longer. Boeing, for example, has a project to help travelers glide through airports on a driverless cart, and Carnegie Mellon is working on robot escorts for those with limited vision. The U.S. Department of Transportation has begun an “accessible transportation” initiative to help people with limited mobility, including older workers. Aaron Steinfeld, a Carnegie Mellon researcher, is helping to develop Tiramisu Transit, a crowdsourced system that can share real-time information about where buses are and which are relatively full or empty. Such data “can be very important for those with balance issues or who use wheelchairs or scooters,” Steinfeld says.

—George Anders

Swelling Ranks of Older Workers

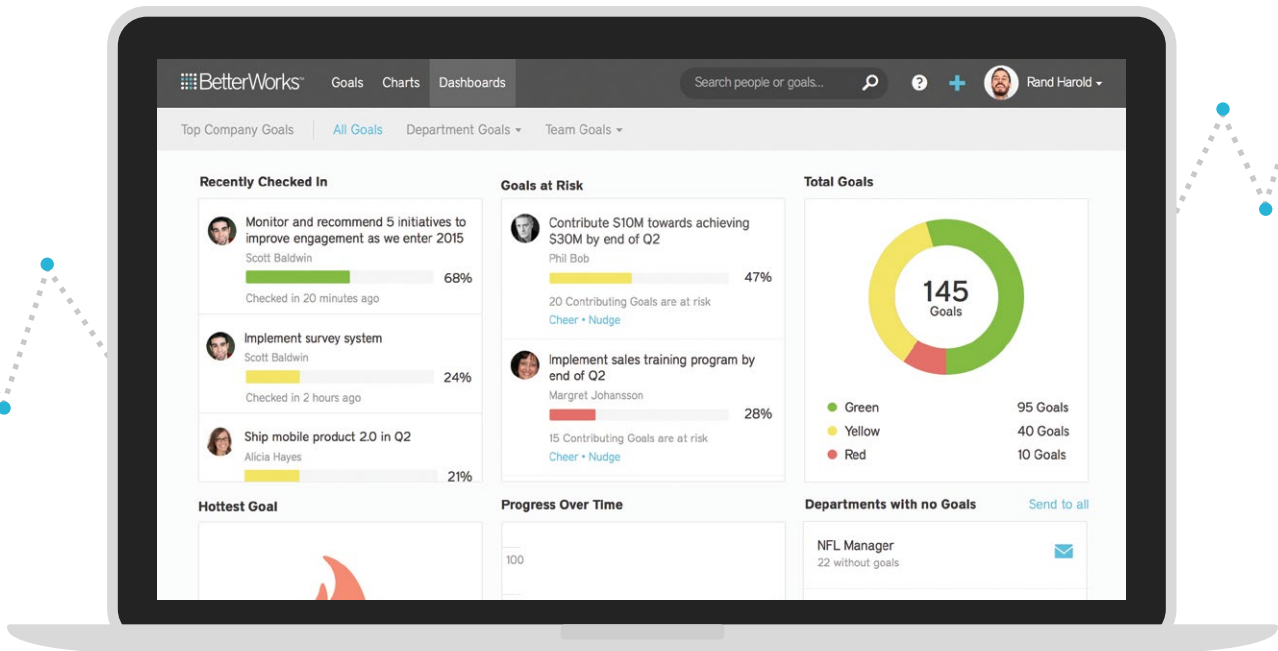
By 2022, more than 8 percent of the U.S. workforce will be 65 or older.

Age: ■ 55–64 ■ 65–74 □ 75+





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Computation and Data Science

Technology Jobs: Radiology

Digitization didn't gut the field, and recent innovations are expanding radiology beyond interpreting images.

● Radiology can date its birth to December 22, 1895, when the German physicist Wilhelm Röntgen shot electromagnetic radiation through his wife's left hand to produce the world's first human radiograph, a black-and-white image of a skeletal hand wearing a wedding ring.

In recent years, the transition from analog to digital imaging and advances in computer-based medical tools have allowed radiologists to access imaging results on a mobile phone or tablet and analyze them immediately. Now, new tools—designed to

teleradiology is used in remote areas and in overnight urgent care.

Technologies beyond digitization, however, have become increasingly important to radiology. Among them are computational medicine and data science.

New applications can reconstruct a tumor in 3-D and precisely measure its volume as it changes over time. "As a radiologist you cannot just stick to the images anymore; you have to be able to use this software," says Wildgruber. "Otherwise you can't deal with the workload."

The increasing complexity of the work and the sheer volume of medical images, which now include video recordings and digital models, have created new challenges, and new opportunities, for companies like IBM and Germany's Brainlab. "A typical emergency room radiologist will do 30 to 40 CT studies, with 2,000 to 3,000 images per study," says Tanveer Syeda-Mahmood, chief scientist for a project at IBM that is developing automated radiology and cardiology tools.

The increasing complexity of the work and the sheer volume of medical images, which now include video recordings and digital models, have created new challenges and new opportunities.

help radiologists deal with a rapidly growing amount of data and make faster, more accurate diagnoses—are changing the job in other unexpected ways.

Asked what a radiologist does, most people are likely to think of a physician sitting alone in a dark lab reading x-rays, says Moritz Wildgruber, a radiologist and researcher at the Klinikum Rechts der Isar hospital in Munich, Germany. At one time digital imaging technology seemed like a potential threat to the profession. Some feared that with "teleradiology," radiographs could be efficiently sent off-site to be read assembly-line-style.

As with many technological shifts, the reality has been more tempered. In part because of strict regulations and liability issues limiting where a scan can be read and by whom, radiology has not been outsourced wholesale. On-site hospital radiology groups remain important, though

"You're easily looking at 100,000 images per day." With all this data—images for one patient might account for 250 gigabytes, says Syeda-Mahmood—a radiologist is at risk of missing the small percentage of images crucial to identifying pathologies.

IBM, which developed the Watson technology that triumphed on *Jeopardy!*, is testing whether similar computer-based reasoning, machine learning, and analytical problem solving modeled on human cognition could ameliorate some of these issues. According to the company, early work has demonstrated that the system can autonomously learn what a pathology looks like—say, an abnormal narrowing in a coronary artery—and automatically alert the radiologist to the most important images for a given patient.

The system is still learning, but Syeda-Mahmood says that in testing it

has achieved over 80 percent accuracy with certain medical conditions—in the range of a good radiologist. Its education could be sped up by having it study the 30 billion images from hospitals, pharmaceutical companies, and clinical research organizations that the company recently acquired in its \$1 billion purchase of Merge Healthcare.

Though Brainlab, whose major markets include North America, is working from a different angle, it too could greatly alter radiology by better utilizing imaging—both diagnostic and interventional—in the operating room.

A neurosurgeon working in an operating room outfitted with Brainlab's image-guided surgery and intraoperative CT systems—like those at the Klinikum Grosshadern, in Munich—is able to visualize tools, anatomy, and radiologic images of diseases overlaid, in real time through a neurosurgeon's scope, on the patient's brain. At the same time, the radiologist can watch live feeds of the surgery in person or remotely, review images and video taken at various stages of the operation, and coordinate treatment.

These technological advances enable radiologists and other physicians to perform more kinds of treatments, including minimally invasive techniques like recanalization of blocked blood vessels and targeted tumor therapies carried out under image guidance.






This blurring of medical portfolios has begun to create conflicts between once-

250 gigabytes

Amount of data one patient's medical images might contain

distinct medical specialties. "If you want to open an occluded artery with a stent," says Wildgruber, "the radiologist can do it, the vascular surgeon can do it, the cardiologist can do it." So whom do you go to when you arrive at the hospital for such a treatment? Today the answer, surprisingly, may come down to which department is available when you walk in.

—Russ Juskalian

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Online Marketplaces

Online and Self-Employed

New technologies give employers access to a world of workers while offering freelancers more ways to build a career.

● Recently Megan Guse has been fielding questions from her former classmates about the atypical path she has taken since graduating from the University of Illinois law school. Three and a half years ago, after finishing a fellowship in the Campaign County state's attorney's office, Guse didn't take the expected next step of joining a law firm or getting a government job. Instead she became an independent contractor. She does legal work, mostly on contracts, for a company called Versata, which specializes in acquiring and restructuring struggling software companies. Headquartered in Austin, Texas, Versata operates globally with almost no full-time employees. Like Guse, most of its workers are contractors.

"I think at first a lot of people viewed it as a questionable move," says Guse. Now, after many of her classmates have begun to burn out on the long hours expected of young lawyers at big firms, "I have sensed a little envy sometimes," she says.

She has little job security, must rely on her husband's employer for health benefits, and does not make the salary she would at a large firm. But she says her earnings are comparable to what she could make as an in-house lawyer at a small company. And she's gotten opportunities to branch out into different types of law, including some recent work on mergers and acquisitions that she wouldn't have done in a more traditional setting. Plus, she works from home, so it was easy to move when her husband's latest job posting took them from Texas to Connecticut.

Those who believe we are headed to a future of contract-based careers like

Guse's cite surveys finding that 53 million Americans do some freelance work today, or the fact that staffing companies have seen a growth in revenue. Companies that operate online marketplaces for freelancers include Upwork, TaskRabbit, Uber, and Amazon Home Services. Many others, from Skype to Slack, facilitate remote work and help contractors run their businesses.

The number of self-employed Americans, as tracked by the government, actually "hasn't moved in two decades," says Lawrence Mishel, president of the Economic Policy Institute. As a percentage of total employment, it has dropped. Depending on whether you include part-time workers, the self-employed, and others, the size of the U.S. contingent workforce is either as small as less than 5 percent of the total or as large as 33 percent.

And while those people have more flexibility and may be able to access a broader range of work in today's digital economy, there are downsides as well. A recent study of the contingent workforce

Freelancing offers flexibility and access to a range of work, but downsides include lower satisfaction and earnings, fewer worker protections and benefits, and job instability.

by the U.S. Government Accountability Office listed lower satisfaction and earnings, fewer protections and benefits, and job instability as some of the disadvantages freelance workers face. Workers' advocates worry that employers will take advantage of the growing digital freelance infrastructure to shift more work off the payroll and more risk onto workers.

These online freelance marketplaces are a global clearinghouse for workers. James Manyika, a director of the research arm of the consulting firm McKinsey, says they could help find work for the 30 to 45 percent of the working-age population worldwide (200 million people) currently either not active at all in the workforce, unemployed, or working part time.

Upwork, the largest of these online marketplaces, has 2.5 million U.S. freelancers. Its contractors collectively earn

more than a billion dollars a year. Building on the technologies underlying social matchmaking sites and the analytical recommendation engines of retailers like Amazon, the company is trying to cut the average time it takes to find someone for a project from three days to three minutes. CEO Stephane Kasriel, who oversees a team of 300 employees and 700 freelancers, says key challenges have included getting the network big enough to make such rapid connections possible and building an algorithm smart enough to start narrowing a would-be employer's search on the basis of just a few questions.

There are particular challenges in building such an algorithm for freelance work. There's no universally accepted taxonomy of skills. Also, freelancers are sometimes simply not available—the best candidate might currently be on a beach somewhere and not interested in work.

A few months ago, no jobs were being filled in three minutes on Upwork's site; now a small number are. Still, searches can take time in fields where talent is

scarce and in demand, like mobile software development, and for jobs that carry a high price tag (projects on the site can bill as much as \$100,000, though most are in the \$100 to \$1,000 range).

While 50 percent of the jobs on the platform come from U.S.-based companies, only 20 percent are filled by U.S. freelancers. Other workers come from India, Eastern Europe, the Philippines, and potentially almost anywhere.

Participants in this global freelance pool wrote and still maintain the software that underlies Brecht Palombo's business, Distressed Pro, a debt database that he sells to investors. He has used freelance software developers from overseas ever since the business launched in 2009, though he needed time to learn the various working styles in different markets. Programmers from the Philippines, for



POWERING GOALS FOR THE ENTERPRISE

1 in 2

senior leaders revise their goals throughout the year

1 in 3

managers revise their goals throughout the year

1 in 5

frontline employees revise their goals in a given year

3.5x

Organizations that set goals quarterly are 3.5x more likely to score in top quartile of business performance ¹

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example, do business in a more Americanized way than those in many parts of Southeast Asia, Palombo says, but they have had challenges like an unreliable power grid and bad weather.

Eventually Palombo began trying to build relationships with a small group of contractors, rather than moving from one to another according to price. “Now I have regular guys who get paid like a salary,” he says. “They are free to work on other things, but I do offer them some security and stability.” He pays experts \$2,000 a month for work that would cost \$8,000 to \$15,000 a month if he hired experienced developers in the U.S., he says.

Beyond managing a remote workforce on Upwork, Palombo has set up a virtual work system. He uses Slack to communicate, schedule and hold meetings, and track assignments. All the work is done using Google programs and is stored in the cloud, where it is safe in the event of a lost laptop or hardware mishap. He organizes assignments and tasks on Trello.

All this has allowed Palombo himself more freedom. He and his wife and three children have spent more than a year traveling the U.S. in an RV, while he works a few hours a day from the road or in a Starbucks. The arrangement hasn’t hurt his business, which he says has grown about 28 percent over the last six months.

—*Nanette Byrnes*

Online Marketplaces

The Homeowner as Hotelier

For some, home-sharing sites like Airbnb have opened up an unexpected second profession.

● Greg Bugay and his wife, Lorraine, live in Fort Lauderdale, Florida, just a short distance from the Atlantic Ocean. They are empty nesters with more space than they need in their duplex. A decade ago, extra bedrooms in tourist havens often sat idle. No more. Today, digital connectivity

has created a simple new line of work for 1.1 million people worldwide: renting out extra rooms for a few days at a time via Airbnb’s home-sharing site.

The Bugays have worked this new calling to perfection. They are among Airbnb’s most active hosts, renting so consistently that their spare bedrooms enjoy a remarkable 92 percent occupancy rate. They hardly need to do any marketing themselves; testimonials from more than 170 previous guests keep sending new visitors their way. All told, the Bugays calculate that they are booking about \$90,000 a year in rental revenue.

Airbnb’s software is so efficient at organizing the rental calendar that Bugay figures it takes only about five hours a week for him and his wife to run their rental business. A few minutes of e-mail correspondence, a little socializing with guests over meals and card games, a round of laundry between visitors, and—voilà—everything is ready for the cycle to continue. If guests don’t speak much English, he says, “we use Google Translate to take care of breakfast requests or some advice about sights to see.”

San Francisco-based Airbnb is not the only company providing an online marketplace for hotel-style rentals in people’s homes. Other major players include VRBO, HomeAway, and FlipKey. But Airbnb, which began as an impromptu online listing by three housemates in 2008, has grown to be the category leader. It operates in 34,000 cities around the world and has rented to more than 40 million guests to date. This year private investors helped fund Airbnb’s further growth at a level that implied a valuation of \$26 billion for the company. That’s more than long-established hotel chains such as Hilton and Marriott command in public stock markets.

Not everyone makes as much money on Airbnb as the Bugays: fewer than 5 percent of its lodging providers qualify as “super hosts.” Typical property owners in cities such as London or Sydney, Australia, earn slightly less than \$5,000 a year, Airbnb calculates, by renting out a room or two intermittently. And the business is not without controversy. Violent

clashes between hosts and guests periodically make headlines, though Airbnb says its vetting systems are designed to avoid this. City governments want Airbnb to collect hotel taxes, which the company generally is willing to do, while affordable-housing advocates sometimes argue that the rise of Airbnb hosting is making life harder for renters. A San Francisco referendum scheduled for November will test whether or not voters want to clamp down on Airbnb’s most active hosts.

81%

Proportion of hosts who rent rooms in their primary residence

52%

Proportion of hosts who have low to moderate income

48%

Proportion of host income used to pay for household expenses like rent

When mass adoption of Internet connectivity took hold in the late 1990s, the travel industry was often cited as an area where the efficiencies afforded by new technology were squeezing out old jobs. Travel agents gave way to do-it-yourself online reservations; guidebooks lost their appeal in the face of competition from YouTube videos and TripAdvisor reviews. But as thrifty travelers make use of Airbnb and similar services, job cuts at hotels may be offset by opportunities in the new informal sector.

Airbnb may even be creating a new entrepreneurial ecosystem. For hosts who don’t want to be bothered with e-mailing confirmation details to their guests (or putting fresh linen on the bed), services such as Pillow, a startup trying to help owners manage their properties, have sprung up. These companies put more people to work, in maid service and clerical support, in return for 15 percent of booking revenue. —*George Anders*

Digital Technology

Freelancers on the Network

New infrastructure based on digital technology is changing the way we work, creating new jobs and requiring workers to develop different skills.

● A large number of workers are moving from working for organizations to freelancing on job networks. Platforms like UpWork, Fiverr, and Freelancer allow freelancers to find a market for their services. Others are more specialized: Dribbble and 99Designs allow designers to find new work, Clarity and Experfy cultivate high-end specialists, and Zaarly and TaskRabbit match workers to lower-end work. Meetup gives freelancers a way to network with peers and learn from them, while Twitter, Medium, Quora, and

The more easily a form of work is commoditized, the more the balance of power will shift away from the worker and toward the platform.

LinkedIn enable these independent workers to build a brand and increase their influence in the market.

As they grow, these platforms will exert greater control over the career prospects and livelihood of the workers who participate. The more easily a form of work is commoditized, the more the balance of power will shift away from the worker and toward the platform. A driver on Uber may be more replaceable or interchangeable with counterparts than a host on Airbnb or a seller on Etsy. Etsy and Airbnb have invested in the community of producers on their platforms, in recognition of their value to consumers. Similarly, Dribbble showcases designers, giving them a way to build their own brand and find high-end work, while 99Designs requires designers to compete with each other for projects. Individuals taking up

networked work will need to strategically choose the platforms where they can most effectively build their reputation and customer base.

The benefits that come with a steady job are offered only piecemeal in the this world of freelance platforms, so networked workers need to be insured against risks associated with participation in alternative markets. For example, hosts on Airbnb run the risk that their apartment will be trashed by a traveler. Independent workers need mechanisms for learning and improvement. To provide them, platforms could invest in community management practices and offer ongoing feedback to users on the basis of past interactions.

Most important, today's networked work environment doesn't offer the stability or health-care benefits of a traditional job: it's not governed by the same sort of social contract. Regulators must create policies to address the issues workers face in this new environment. Third parties not associated with spe-

cific platforms could also develop new businesses offering these services to networked workers, to substitute for what traditional employers once provided.

The careers of the past depended on our ability to leverage relationships in offline professional networks. The careers of the future will depend on our ability to leverage online networked platforms. Workers' reputation on these labor platforms, and their ability to build a business across multiple platforms without becoming overtly dependent on one, will determine success in the age of networked work.

—Sangeet Paul Choudary

The author, founder of Platform Thinking Labs, thanks Geoffrey Parker and Marshall Van Alstyne for ideas contributed to this article.

Outside Reading

Rise of the Robots: Technology and the Threat of a Jobless Future

by Martin Ford

Basic Books, May 2015

A Silicon Valley entrepreneur discusses how advances in robotics could wipe out jobs and deepen inequality.

The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies

by Erik Brynjolfsson and

Andrew McAfee

W.W. Norton, January 2014

In this *New York Times* best-seller, two leading thinkers at MIT discuss how industries will have to adapt to a world where computers can do many jobs better than humans can.

Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots

by John Markoff

Ecco, August 2015

Pulitzer Prize-winning science writer John Markoff details the history of interactions between humans and robots.

"Who Will Own the Robots?"

by David Rotman

MIT Technology Review,

July/August 2015

In this cover story, *MIT Technology Review* editor David Rotman explores how increased automation is affecting jobs and how the economic benefits of technology can be more fairly shared.

The Glass Cage: Automation and Us

by Nicholas Carr

W.W. Norton, September 2014

A best-selling author looks at how automation is affecting several facets of

our lives, including cars, wearables, and factory robots.

***Virtually Human:
The Promise—and the Peril—
of Digital Immortality***

by Martine Rothblatt
St. Martin's Press, September 2014

Entrepreneur Martine Rothblatt looks at what could happen if software becomes part of our brains.

Superintelligence: Paths, Dangers, Strategies

by Nick Bostrom
Oxford University Press, September 2014

Can humans stay in control when machines become smarter than we are? Philosopher Nick Bostrom explores questions like these in this book, recommended by both Bill Gates and Elon Musk.

***The Future of Employment:
How Susceptible Are Jobs to
Computerisation?***

by Carl Benedikt Frey and Michael A. Osborne
University of Oxford, September 2013

This report looks at how vulnerable certain workers are to being replaced by robots.

“Will Your Job Be Done by a Machine?”

by Quoc Trung Bui
Planet Money, May 2015

NPR has turned the above-mentioned Oxford study into an interactive graphic that readers can use to determine the likelihood of losing their job to a robot.

AI, Robotics, and the Future of Jobs

by Aaron Smith and Janna Anderson
Pew Research Center, August 2014

This report from a prominent think tank explores how the rise of robots could affect humans' jobs.

World Robotics: Industrial Robots 2014, Executive Summary

International Federation of Robotics,
2014

An oft-cited report on industrial robot sales.

“Technology and Inequality”

by David Rotman
MIT Technology Review,
November/December 2014

The gap between the very rich and poor is especially wide in Silicon Valley. David Rotman attempts to find out how much technology has to do with it.

Fastest Declining Occupations, 2012 and projected 2022

Employment Statistics Program, U.S. Department of Labor, Bureau of Labor Statistics, December 2013

U.S. government data shows which jobs are expected to decline the most quickly over the next decade.

Learning by Doing: The Real Connection between Innovation, Wages, and Wealth

By James Bessen
Yale University Press, 2015

Much of the value from innovations comes over time as they are implemented, the author argues, and while technology transforms work in profound ways, it can take a long time for workers and society to fully adapt.

“Technology and People: The Great Job Creating Machine”

Ian Stewart, Debapratim De, and Alex Cole
Deloitte, December 2014

This study of employment data from England and Wales over the last 140 years concludes that when machines replace workers, the result is faster growth and rising overall employment. Though the authors don't attempt to

forecast the jobs of the future, they conclude that work will increasingly focus on factors that cannot be automated, including social interaction and empathy, creativity, and skill.

“A World without Work”

By Derek Thompson
The Atlantic, July/August 2015

For centuries, experts have predicted that machines would make workers obsolete. If that moment has finally arrived, could it be a good thing?

Calendar

Next: Economy

November 12–13, 2015
San Francisco
<http://conferences.oreilly.com/next-economy>

Robotics Alley Conference & Expo

December 1–2, 2015
Minneapolis
<http://roboticsalley.org/>

11th ACM/IEEE International Conference on Human-Robot Interaction (HR1 2016)

March 7–10, 2016
Christchurch, New Zealand
<http://humanrobotinteraction.org/2016/>

ICRA 2016: IEEE International Conference on Robotics and Automation

May 16–21, 2016
Stockholm, Sweden
www.icra2016.org

RoboBusiness Europe

June 1–3, 2016
Odense, Denmark
www.robobusiness.eu/rb/

IEEE CASE 2016

August 21–25, 2016
Fort Worth, Texas
<http://sites.ieee.org/case-2016/>

IROS 2016

October 9–14, 2016
Daejeon, Korea
www.iros2016.org

Automate

April 3–6, 2017
Chicago
www.autmateshow.com