The New York Times

August 18, 2012

Skilled Work, Without the Worker

By JOHN MARKOFF

DRACHTEN, the Netherlands — At the Philips Electronics factory on the coast of China, hundreds of workers use their hands and specialized tools to assemble electric shavers. That is the old way.

At a sister factory here in the Dutch countryside, 128 robot arms do the same work with yoga-like flexibility. Video cameras guide them through feats well beyond the capability of the most dexterous human.

One robot arm endlessly forms three perfect bends in two connector wires and slips them into holes almost too small for the eye to see. The arms work so fast that they must be enclosed in glass cages to prevent the people supervising them from being injured. And they do it all without a coffee break — three shifts a day, 365 days a year.

All told, the factory here has several dozen workers per shift, about a tenth as many as the plant in the Chinese city of Zhuhai.

This is the future. A new wave of robots, far more adept than those now commonly used by automakers and other heavy manufacturers, are replacing workers around the world in both manufacturing and distribution. Factories like the one here in the Netherlands are a striking counterpoint to those used by Apple and other consumer electronics giants, which employ hundreds of thousands of low-skilled workers.

“With these machines, we can make any consumer device in the world,” said Binne Visser, an electrical engineer who manages the Philips assembly line in Drachten.

Many industry executives and technology experts say Philips’s approach is gaining ground on Apple’s. Even as Foxconn, Apple’s iPhone manufacturer, continues to build new plants and hire thousands of additional workers to make smartphones, it plans to install more than a million robots within a few years to supplement its work force in China.

Foxconn has not disclosed how many workers will be displaced or when. But its chairman,

Terry Gou, has publicly endorsed a growing use of robots. Speaking of his more than one million employees worldwide, he said in January, according to the official Xinhua news agency: “As human beings are also animals, to manage one million animals gives me a headache.”

The falling costs and growing sophistication of robots have touched off a renewed debate among economists and technologists over how quickly jobs will be lost. This year, Erik Brynjolfsson and Andrew McAfee, economists at the Massachusetts Institute of Technology, made the case for a rapid transformation. “The pace and scale of this encroachment into human skills is relatively recent and has profound economic implications,” they wrote in their book, “Race Against the Machine.”

In their minds, the advent of low-cost automation foretells changes on the scale of the revolution in agricultural technology over the last century, when farming employment in the United States fell from 40 percent of the work force to about 2 percent today. The analogy is not only to the industrialization of agriculture but also to the electrification of manufacturing in the past century, Mr. McAfee argues.

“At what point does the chain saw replace Paul Bunyan?” asked Mike Dennison, an executive at Flextronics, a manufacturer of consumer electronics products that is based in Silicon Valley and is increasingly automating assembly work. “There’s always a price point, and we’re very close to that point.”

But Bran Ferren, a veteran roboticist and industrial product designer at Applied Minds in Glendale, Calif., argues that there are still steep obstacles that have made the dream of the universal assembly robot elusive. “I had an early naïveté about universal robots that could just do anything,” he said. “You have to have people around anyway. And people are pretty good at figuring out, how do I wiggle the radiator in or slip the hose on? And these things are still hard for robots to do.”

Beyond the technical challenges lies resistance from unionized workers and communities worried about jobs. The ascension of robots may mean fewer jobs are created in this country, even though rising labor and transportation costs in Asia and fears of intellectual property theft are now bringing some work back to the West.

Take the cavernous solar-panel factory run by Flextronics in Milpitas, south of San Francisco. A large banner proudly proclaims “Bringing Jobs & Manufacturing Back to California!” (Right now China makes a large share of the solar panels used in this country

and is automating its own industry.)

Yet in the state-of-the-art plant, where the assembly line runs 24 hours a day, seven days a week, there are robots everywhere and few human workers. All of the heavy lifting and almost all of the precise work is done by robots that string together solar cells and seal them under glass. The human workers do things like trimming excess material, threading wires and screwing a handful of fasteners into a simple frame for each panel.

Such advances in manufacturing are also beginning to transform other sectors that employ millions of workers around the world. One is distribution, where robots that zoom at the speed of the world's fastest sprinters can store, retrieve and pack goods for shipment far more efficiently than people. Robots could soon replace workers at companies like C & S Wholesale Grocers, the nation's largest grocery distributor, which has already deployed robot technology.

Rapid improvement in vision and touch technologies is putting a wide array of manual jobs within the abilities of robots. For example, Boeing's wide-body commercial jets are now riveted automatically by giant machines that move rapidly and precisely over the skin of the planes. Even with these machines, the company said it struggles to find enough workers to make its new 787 aircraft. Rather, the machines offer significant increases in precision and are safer for workers.

And at Earthbound Farms in California, four newly installed robot arms with customized suction cups swiftly place clamshell containers of organic lettuce into shipping boxes. The robots move far faster than the people they replaced. Each robot replaces two to five workers at Earthbound, according to John Dulchinos, an engineer who is the chief executive at Adept Technology, a robot maker based in Pleasanton, Calif., that developed Earthbound's system.

Robot manufacturers in the United States say that in many applications, robots are already more cost-effective than humans.

At an automation trade show last year in Chicago, Ron Potter, the director of robotics technology at an Atlanta consulting firm called Factory Automation Systems, offered attendees a spreadsheet to calculate how quickly robots would pay for themselves.

In one example, a robotic manufacturing system initially cost $250,000 and replaced two machine operators, each earning $50,000 a year. Over the 15-year life of the system, the machines yielded $3.5 million in labor and productivity savings.

The Obama administration says this technological shift presents a historic opportunity for the nation to stay competitive. “The only way we are going to maintain manufacturing in the U.S. is if we have higher productivity,” said Tom Kalil, deputy director of the White House Office of Science and Technology Policy.

Government officials and industry executives argue that even if factories are automated, they still are a valuable source of jobs. If the United States does not compete for advanced manufacturing in industries like consumer electronics, it could lose product engineering and design as well. Moreover, robotics executives argue that even though blue-collar jobs will be lost, more efficient manufacturing will create skilled jobs in designing, operating and servicing the assembly lines, as well as significant numbers of other kinds of jobs in the communities where factories are.

And robot makers point out that their industry itself creates jobs. A report commissioned by the International Federation of Robotics last year found that 150,000 people are already employed by robotics manufacturers worldwide in engineering and assembly jobs.

But American and European dominance in the next generation of manufacturing is far from certain.

“What I see is that the Chinese are going to apply robots too,” said Frans van Houten, Philips’s chief executive. “The window of opportunity to bring manufacturing back is before that happens.”

A Faster Assembly Line

Royal Philips Electronics began making the first electric shavers in 1939 and set up the factory here in Drachten in 1950. But Mr. Visser, the engineer who manages the assembly, takes pride in the sophistication of the latest shavers. They sell for as much as $350 and, he says, are more complex to make than smartphones.

The assembly line here is made up of dozens of glass cages housing robots made by Adept Technology that snake around the factory floor for more than 100 yards. Video cameras atop the cages guide the robot arms almost unerringly to pick up the parts they assemble. The arms bend wires with millimetric accuracy, set toothpick-thin spindles in tiny holes, grab miniature plastic gears and set them in housings, and snap pieces of plastic into place.

The next generation of robots for manufacturing will be more flexible and easier to train.

Witness the factory of Tesla Motors, which recently began manufacturing the Tesla S, a luxury sedan, in Fremont, Calif., on the edge of Silicon Valley.

More than half of the building is shuttered, called “the dark side.” It still houses a dingy, unused Toyota Corolla assembly line on which an army of workers once turned out half a million cars annually.

The Tesla assembly line is a stark contrast, brilliantly lighted. Its fast-moving robots, bright Tesla red, each has a single arm with multiple joints. Most of them are imposing, 8 to 10 feet tall, giving them a slightly menacing “Terminator” quality.

But the arms seem eerily human when they reach over to a stand and change their “hand” to perform a different task. While the many robots in auto factories typically perform only one function, in the new Tesla factory a robot might do up to four: welding, riveting, bonding and installing a component.

As many as eight robots perform a ballet around each vehicle as it stops at each station along the line for just five minutes. Ultimately as many as 83 cars a day — roughly 20,000 are planned for the first year — will be produced at the factory. When the company adds a sport utility vehicle next year, it will be built on the same assembly line, once the robots are reprogrammed.

Tesla’s factory is tiny but represents a significant bet on flexible robots, one that could be a model for the industry. And others are already thinking bigger.

Hyundai and Beijing Motors recently completed a mammoth factory outside Beijing that can produce a million vehicles a year using more robots and fewer people than the big factories of their competitors and with the same flexibility as Tesla’s, said Paul Chau, an American venture capitalist at WI Harper who toured the plant in June.

The New Warehouse

Traditional and futuristic systems working side by side in a distribution center north of New York City show how robotics is transforming the way products are distributed, threatening jobs. From this warehouse in Newburgh, C & S, the nation’s largest grocery wholesaler, supplies a major supermarket chain.

The old system sprawls across almost half a million square feet. The shelves are loaded and unloaded around the clock by hundreds of people driving pallet jacks and forklifts. At peak

times in the evening, the warehouse is a cacophony of beeping and darting electric vehicles as workers with headsets are directed to cases of food by a computer that speaks to them in four languages.

The new system is much smaller, squeezed into only 30,000 square feet at the far end of the warehouse and controlled by just a handful of technicians. They watch over a four-story cage with different levels holding 168 “rover” robots the size of go-carts. Each can move at 25 miles an hour, nearly as fast as an Olympic sprinter.

Each rover is connected wirelessly to a central computer and on command will race along an aisle until it reaches its destination — a case of food to retrieve or the spot to drop one off for storage. The robot gathers a box by extending two-foot-long metal fingers from its side and sliding them underneath. It lifts the box and pulls it to its belly. Then it accelerates to the front of the steel cage, where it turns into a wide lane where it must contend with traffic — eight robots are active on each level of the structure, which is 20 aisles wide and 21 levels high.

From the aisle, the robots wait their turn to pull into a special open lane where they deposit each load into an elevator that sends a stream of food cases down to a conveyor belt that leads to a large robot arm.

About 10 feet tall, the arm has the grace and dexterity of a skilled supermarket bagger, twisting and turning each case so the final stack forms an eight-foot cube. The software is sophisticated enough to determine which robot should pick up which case first, so when the order arrives at the supermarket, workers can take the cases out in the precise order in which they are to go on the shelves.

When the arm is finished, the cube of goods is conveyed to a machine that wraps it in clear plastic to hold it in place. Then a forklift operator summoned by the computer moves the cube to a truck for shipment.

Built by Symbotic, a start-up company based in the Boston area, this robotic warehouse is inspired by computer designers who created software algorithms to efficiently organize data to be stored on a computer’s hard drive.

Jim Baum, Symbotic’s chief executive, compares the new system to a huge parallel computer. The design is efficient because there is no single choke point; the cases of food moving through the robotic warehouse are like the digital bits being processed by the computer.

Humans' Changing Role

In the decade since he began working as a warehouseman in Tolleson, Ariz., a suburb of Phoenix, Josh Graves has seen how automation systems can make work easier but also create new stress and insecurity. The giant facility where he works distributes dry goods for Kroger supermarkets.

Mr. Graves, 29, went to work in the warehouse, where his father worked for three decades, right out of high school. The demanding job required lifting heavy boxes and the hours were long. "They would bring in 15 guys, and only one would last," he said.

Today Mr. Graves drives a small forklift-like machine that stores and retrieves cases of all sizes. Because such workers are doing less physical labor, there are fewer injuries, said Rome Aloise, a Teamsters vice president in Northern California. Because a computer sets the pace, the stress is now more psychological.

Mr. Graves wears headsets and is instructed by a computerized voice on where to go in the warehouse to gather or store products. A centralized computer the workers call The Brain dictates their speed. Managers know exactly what the workers do, to the precise minute.

Several years ago, Mr. Graves's warehouse installed a German system that automatically stores and retrieves cases of food. That led to the elimination of 106 jobs, roughly 20 percent of the work force. The new system was initially maintained by union workers with high seniority. Then that job went to the German company, which hired nonunion workers.

Now Kroger plans to build a highly automated warehouse in Tolleson. Sixty union workers went before the City Council last year to oppose the plan, on which the city has not yet ruled.

"We don't have a problem with the machines coming," Mr. Graves told city officials. "But tell Kroger we don't want to lose these jobs in our city."

Some jobs are still beyond the reach of automation: construction jobs that require workers to move in unpredictable settings and perform different tasks that are not repetitive; assembly work that requires tactile feedback like placing fiberglass panels inside airplanes, boats or cars; and assembly jobs where only a limited quantity of products are made or where there are many versions of each product, requiring expensive reprogramming of robots.

But that list is growing shorter.

Upgrading Distribution

Inside a spartan garage in an industrial neighborhood in Palo Alto, Calif., a robot armed with electronic "eyes" and a small scoop and suction cups repeatedly picks up boxes and drops them onto a conveyor belt.

It is doing what low-wage workers do every day around the world.

Older robots cannot do such work because computer vision systems were costly and limited to carefully controlled environments where the lighting was just right. But thanks to an inexpensive stereo camera and software that lets the system see shapes with the same ease as humans, this robot can quickly discern the irregular dimensions of randomly placed objects.

The robot uses a technology pioneered in Microsoft's Kinect motion sensing system for its Xbox video game system.

Such robots will put automation within range of companies like Federal Express and United Parcel Service that now employ tens of thousands of workers doing such tasks.

The start-up behind the robot, Industrial Perception Inc., is the first spinoff of Willow Garage, an ambitious robotics research firm based in Menlo Park, Calif. The first customer is likely to be a company that now employs thousands of workers to load and unload its trucks. The workers can move one box every six seconds on average. But each box can weigh more than 130 pounds, so the workers tire easily and sometimes hurt their backs.

Industrial Perception will win its contract if its machine can reliably move one box every four seconds. The engineers are confident that the robot will soon do much better than that, picking up and setting down one box per second.

"We're on the cusp of completely changing manufacturing and distribution," said Gary Bradski, a machine-vision scientist who is a founder of Industrial Perception. "I think it's not as singular an event, but it will ultimately have as big an impact as the Internet."