Robots and the Future of Work

by

Edmund Byrne

The Automation Revolution, prophesied from the outset of the Industrial Revolution[1] and prematurely announced following development of the computer after World War II,[2] is now on the verge of realization, thanks to the discovery and inexpensive mass production of compact and versatile microprocessors that make possible so-called "smart" robots and other components of automated assembly systems. First exploited by the Japanese, robotization is likely to be (perhaps along with biotechnology) the single most significant characteristic of technological history in the 1980s. And when the decade is over, the configuration of human work will have been radically transformed, along with the technology that undergirds and now increasingly is replacing it.

In a word, many humans are going to lose their jobs. Whether they will find others that need doing or that they are qualified to do is a very hard question to answer. But it is one that society will be required to answer; and the answer that society comes up with will determine in a very fundamental way the future of the human condition.[3] As of now, however, there is no adequate plan for a social equivalent of Isaac Asimov's third law of robotics, namely, that a robot should never harm a human. Robots will harm humans. They are doing so already. Not by crudely striking a blow to the head, but just by being able to do better what humans have been doing poorly by default. In the process, of course, robots will be sparing humans a lot of pain, but the pain associated with sweat on the brow is as nothing compared to the pain of being unemployed and unemployable. And that, quite clearly, is just what lies ahead for people in all parts of the world, especially in developed nations.

Questions to be considered, then, are the following. What is a robot? What can robots do? What impact will robots have on human work? And what, if anything, should humans do about "keeping robots in their place"?

What Is a Robot

There are three definitions of the word *robot*, only two of which are

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relevant here. The most common (in popular usage as well as in science fiction) is that of a manufactured apparatus that has a humanoid appearance and exercises humanlike functions well enough to be considered human in a given context. There are, in fact, robots of this type in use, e.g., to direct pedestrian and/or vehicular traffic.[4] But the presence or absence of humanlike features is of no importance in the discussion that follows.

A second definition of the word *robot* is a programmable manipulator of versatile automation components. This is the usage generally accepted by industry people. A third and considerably narrower definition, favored by research and development people, is an artificial intelligence machine with humanlike functions. Programmable automation manipulators have been around for decades. "AI" machines are only now beginning to make their appearance but are expected to mushroom in the decade ahead. It is important but not always easy to determine which definition is being invoked by a writer or speaker on the subject, especially when one is trying to count the number of robots in a plant or industry, in a particular country (e.g., Japan), or in the world. Unless noted otherwise, I shall take "robot" in the broader sense as including all programmable automation manipulators.

Robots are distinguishable with regard to degrees of freedom, method of articulation, control of motion, or method of actuation. Three degrees of freedom are required to position an object in space, three more to orient the object in any direction (a minimum for a "general-purpose manipulator"). Robot joints may swivel ("polar"), slide ("cartesian"), or combine these two methods ("cylindrical"). Only a terminal point is specified in point-to-point control; the precise path and the velocity of the entire movement are determined by continuous-path control. Pneumatic actuation of a robot is cheap and simple but adequate only for point-to-point operations. Electric actuation is simple to install and easy to maintain; a hydraulic system yields better dynamic performance and power-to-weight ratio.

Jasia Reichardt identifies nine levels of automation (she calls them "stages, or degrees"), with robots entering the scene on the fifth level. If the task to be performed is bending a pipe and some tool is employed in the process, the pre-robotic tool might be (1) a hand tool, (2) a power tool, (3) power machinery under human control, (4) powered machinery executing a programmed sequence of operations without variation. A robotic tool bending a pipe might be (5) pre-programmed only for that task as to sequence of and length of time between operations; (6) provided with several programs stored and selected automatically (a variable sequence robot), (7) controlled by means of programs stored in a large memory device and subject to change automatically (continuous-path robots with servomechanisms), (8) a computer-aided manufacturing system that activates the motors of numerically controlled robots by means of programs stored on punched paper tape, or (9) "blue collar" or "smart" or "intelligent" robots with tactile and visual capabilities. Only the latter, which utilize only recently feasible "artificial intelligence," are considered true robots by experts in this field.

According to one estimate, there are some 15,000 robots installed around the world, about half of which are in Japan and a fourth in the United States.[5] In second place is the Soviet Union, where there are now some 6–7,000 units, but most of these are technologically retarded, having only 3–4 axes of movement.[6]

Far more important for the future of work in the world are projections for the growth of robot usage in the decades ahead. In the next five years the Russians plan to add 40,000 additional units, and during the five years thereafter they will be installing sensory robots. One hundred and fifty companies in Japan produced robots (five times as many as in the United States) at a level of $400 million in 1980, and expect to be producing at a level of $2.2 billion in 1985, $4.5 billion in 1990.[7] In the United States, robot production was at a level of $50 million/year in 1981, but may expand to $250 billion over the next 20 years.[8]

The key factor in the upcoming expansion of robot production and use is not the quantity of dollars or units but the quality, that is, the capabilities, of the units to be produced. As Reichardt observes, "One has to prepare and present data in a way in which a robot can use them, which means that the cost of equipping a factory for robot operation may be ten times the cost of the robots themselves. The need exists, therefore, to design robots capable of working in moderate disorder, with some ability to recognize colors, shadows, markings, and textures."[9]

This challenge is now beginning to be met by artificial intelligence, which utilizes increasingly sophisticated microelectronic technology to solve problems heuristically. To this end, robots must have "sensory" capability, in varying degrees depending on the task, both in regard to "touch" and in regard to "vision," and both are now becoming technologically and economically feasible. A Mitsubishi robot, for example, "knows" when it has reached the correct object on a workbench by comparing images of it in two television cameras, one mounted on the robot's hand and the other overlooking the workbench. A Hitachi robot is so touch-sensitive that it can insert a piston into a cylinder with a clearance of 20 microns in three seconds. Selective choice and evaluation of parts will be coming soon. Still in the future is a "thinking" robot that when shown what to do will establish the most efficient way of doing it.[10]

What Impact Will Robots Have on the Work Force?

What impact is all this likely to have on the human work force? The answer to this question is all too simple: humans will be rendered superfluous and displaced. This much is fairly certain. All that remains uncertain is the scope of the displacement. But there are already indications that it will soon be extensive and will eventually be massive.

In the period 1990–2000, according to one projection, robots and automated systems will be producing half of all manufactured goods and, as a result, up to one-quarter of the factory work force may be dislodged.[11]

That this will come about seems an inevitable outcome of the belief common among industrialists that it will be cost effective in the long run and for that very reason is a necessary condition for staying competitive in the industries affected. Estimates vary as to just how much less expensive it may be to use robots rather than humans. As one writer puts it, a Japanese robot in automotive production can do at $5.50/hr. what a UAW worker does for $18.10/hr. (wages and fringes).[12]

Other factors, including not only OPEC but also the almost total unwillingness of U.S. auto manufacturers to deviate from 60-year-old production methods, have helped bring about the current disarray, if not imminent disappearance, of the U.S. auto industry. But robotics, if ever really taken seriously, might make a difference. At least, such is the impression of those who still believe that an old dinosaur can be taught new tricks. And this belief is quite enough to put the automotive work force on notice.

Fiat's Robogate system boosted production 15% in 1978, we are reminded, but replaced few workers. But with sensory robots the Italian manufacturer could, it is estimated, cut manpower 90% before 1990.[13] This lesson has not been lost on General Motors, which will be spending $200 million by 1983 to install 800 robots on 14 assembly lines in 7 of its plants in Italy. And by 1990, GM will have invested $1 billion in 13,000 robots to paint, load/unload machines, and assemble components, with the help of Robogate, thereby cutting labor costs by an estimated 70% and the labor force by 50% just in the next nine years.[14] However impressive these numbers may be in a vacuum, they may well be too little too late: from its present total of 450 robots, GM hopes to expand to 5,000 by 1985 and to 13,000 by 1990—but the Japanese already have 7,000 in place! And they have no more intention of yielding the lead in robotics than in electronics in general. MITI, the quasi-governmental research arm of Japanese industry, plans to spend $140 million over a seven-year period to develop smart robots to assemble an entire product, such as an automobile, beginning as early as 1983. With this new system, one could effect changeover simply by changing the system's software. By 1985, Hitachi hopes to be using robots with visual and tactile sensors for 60% of its assembly operations. And three major Japanese companies are working on a robot that will be able to position a component within four-hundredths of an inch. One of these companies, Fujitsu Fanuc Ltd., has opened a $38 million plant to produce other robots and computerized tools automatically, using robots, numerically controlled machine tools, and only one shift of 100 human workers to assemble robot-made parts (until, that is, robots start doing even that).[15]

By comparison to the Japanese commitment to robotics, American auto makers are in a technological feudal age. But even belatedly introduced technology is having an effect on the work force. Take the example of the PUMA (programmable universal machine for assembly), a $20,000 robot arm developed by GM and Unimation. By 1990, GM expects to be using 5,000 of these in assembly work and 4,000 to load/unload machines, thereby bumping 50% of assembly-line laborers.[16]

Another industry on the verge of transformation by robotics is that of consumer appliances, which in the United States is dominated by General Electric. GE had two robots in 1978, added 26 more in 1979, and may be using 1,000 by the end of this decade. The company spent over $15 million in 1980 for 47 new robots expected to save $2.6 million/year in labor and materials. So far, displaced assembly workers have been transferred, e.g., to robot maintenance, with work-force reduction being limited to attrition.[17] For example, GE's dishwasher plant in Louisville, Kentucky, is 60% automated, but workers are free to stop the line at key points to prevent defects from being built in. But the technology for full-scale automation, including a robotic "eye" and a CAD/CAM (computer-aided design and manufacture) system, has been under development.[18] And once this is in place, reduction in work force will follow. In fact, GE plans to robotize as many as half of its 37,000 assembly-line jobs to achieve 6% per year improvement in productivity.[19] Nor does the company really have much choice in the matter because of new competition from Japanese manufacturers such as Sanyo, which has opened an automated refrigerator plant on the West Coast and others in Tennessee, Arkansas, and other states.

GE's in-house robotization agenda is, however, only the tip of the iceberg. GE is now bent on supplying robots and other automation equipment to other manufacturers. To this end, the company has acquired licenses to use robotics technology developed by Italy's Digital Electronic Automation, Japan's Hitachi, and most recently, Volkswagenwerk. According to reports, the arrangement with VW will authorize GE to build five of that company's robot models and sell them worldwide. These additions will give GE a total of 12 models, including one capable of handling components weighing more than 200 pounds, which will be of interest to the automotive, aerospace, and heavy equipment industries.[20]

Nor is GE going to be lonesome in the robot marketplace. In addition to smaller companies such as Cincinnati Milacron and Unimation, which turn out $30–40 million worth of robots a year, and Automatrix, the race for what could be a $25 billion market by 1990 has been joined by such giants as Digital Equipment, IBM, and Texas Instruments. One result of this expanded interest is that the cost of a $50,000 robot is expected to drop to $10,000 by the end of the decade. And the result of all these factors may be, according to one projection, that "smart robots could displace 65% to 75% or more of today's factory work force."

Be that as it may, there are customers for robots almost literally waiting in line for delivery. A new Robotics Division at Westinghouse, for example, has a mandate to robotize "any and all manufacturing areas." And toward this end the company, like others around the country, has been doing a feasibility study (on NSF money) of automated batch-assembly of 450 different versions of eight different fractional-horsepower motors at a rate of 1 million units/year. Cybotech, a joint venture between Renault and Ransberg Corporation, an Indianapolis-based company, has been providing robots on a turnkey basis, if desired, to such diverse companies as General Motors, Jeep Corporation, Lockheed, and Caterpillar Tractor, with Renault spending $6.2 million/year on visual R&D and Cybotech $2.5 million/year on sensile/tactile technology.[21] More generally, it is estimated that U.S. industry will more than triple its 1981 automation investments to $5 billion in 1985, this amount to be divided about equally between computer-aided design (CAD) and such devices as minicomputers, numerical controls, programmable controls, and robots.[22]

Thanks to this new technology, especially microcomputers and so-called "friendly" (ordinary language) software, production programs can be changed right on the factory floor for customized batch production in runs of less than 50 units. And this, in turn, means perhaps a 30% decrease in use of workers, commonly by introducing an unmanned third shift—what in German is called the ghost shift ("*die Geisterschicht*"). The Japanese, however, are prepared to go this stunt one better: *flexible manufacturing complex* (FMC), a $60 million prototype of which is now in place, with the expectation that 20% of Japan's total factory output will be FMC'd by 1985. What FMC involves is five fully automatic manufacturing operations all interconnected and controlled by a hierarchy of computers, with humans on hand only as safety overseers of lasers used for treating and machining.

As these examples have suggested, the impact of the "new wave" of automation on blue-collar unions may turn out to be absolutely devastating. The United Auto Workers expect to lose 200,000 of their 1 million members between 1978 and 1990. The IUE, the International Association of Machinists, and the International Brotherhood of Electrical Workers will also be hard hit. But so also will white-collar personnel—possibly as many as 38 million of the present 50 million white-collar jobs may be affected, just as automation has already reduced employment in the U.S. Postal Service from 744,000 in 1970 to 677,000 in 1981: a 10% reduction. At racetracks, window betting is being taken over by an automated "sell-pay" system that shortens line, saves 10–50% on costs of operation, and eliminates jobs. Similarly, when U.S. air traffic controllers went on strike in 1981, their complaint about job stress was, if anything, counterproductive. For the U.S. government is engaged in a 10-year $8.5 billion project to reduce the need for technicians and controllers by one-third with an automated ATC system that would require only one rather than three humans per display screen, thus allegedly saving $6.7 billion in the 1980s and over $17 billion in the 1990s.[23]

Examples such as these could be multiplied, but the point is clear: a very significant number of jobs are on the block in the decade ahead, not only in the United States but in other countries as well. If it is any consolation, the traumas of transition are at least as likely in Western Europe.[24] And in Japan, the world's leader in automation, it may well prove to be catastrophic. In that country, workers in manufacturing dropped from 14.4 million in 1973 to 13.7 million in 1980. Six million workers in cottage industries still represent 81% of Japan's 55.4 million workers, but these are being replaced by more reliable robots. The country has need of 745,000 computer software engineers, but it now has less than 100,000. Even jobs available as robot tenders are difficult to fill because the Japanese are not accustomed to working on any but the normal daytime shift. The conclusion of a government study that the impact of microelectronics on employment is not serious is much criticized; but the government is doing little to create new jobs.[25] Nor is this a problem only in developed countries. As is well known, electronics manufacturers have in years past gone to places such as South Korea, Taiwan, Hong Kong, and Singapore for low-level assembly operations. But computer-controlled assembly in the

United States and Japan is now competitive with labor-intensive production elsewhere, and the result may be the end of an era for these developing Asian countries.

What is suggested by all these details is that, as has occurred before in history, the human cost of progress may be excruciatingly high. That there will in time be protests and demonstrations, if not worse, seems inevitable. But in this instance, unlike that of popular protest against nuclear power plants, the economics (if the "experts" can be believed) would oppose rather than support the sentiments of the protesters. However, as is commonly the case, only internal costs are being figured, not the external costs, direct and indirect, that spill over onto society in the wake of a technological upheaval of the magnitude that lies ahead. So, as our own federal government prepares to abandon CETA and other relevant and timely social service programs, and state governments do little to fill the vacuum, we in the United States are left with little reason to gloat over the plight of the Japanese worker.

What Can We Do About Displaced Workers?

What possible remedies are there for the severe dislocations that this inevitable revolution is bringing over the horizon? The obvious answer, namely, that anyone laid off should get another job, seems especially cynical at a time of high unemployment. In addition, the factor of high interest rates intensifies the trauma of relocation, if that is required. Nor can an unskilled laborer count on finding employment even if willing to move. Even those who are still at work on assembly lines may find that computers are being used to subject them to time-study; and should they decide to strike in protest, they may become the victims of what one UAW official calls "technological scabbing." A short-term solution, of course, is to find ways to pace the introduction of automation, regulate the use of time-study, and participate in decision-making with regard to new technological systems on the basis of appropriate and adequate data.

Moreover, if unions want to protect their members, they need to have more control over job skills required by the new computer-based technology, e.g., diagnosis of problems by an electrician; programming and editing of numerical control tapes, robots, and all other "programmable automation," including work on machines that are leased or under warranty; and, by way of corollary, adequate training for performance of such jobs.

Unfortunately, outside of a few countries, notably in Scandanavia, presently available retraining programs are neither adequate nor effective to deal with the anticipated impact of robotics.

Above and beyond the comparatively short-term needs for programs to assist displaced workers, there is an endemic long-term need to rethink and restructure our educational system to provide the next generation of workers with the kinds of skills they must have to find employment in the decades ahead. Not that every student needs to become adept at microelectronics or biogenetics or whatever. But the socioeconomic consequences of the coming shift in technology require us to anticipate and prepare for a radically different society that we dare not approach behind a veil of ignorance.

As we contemplate this profound challenge, we will look in vain for ethical theories that can guide our search for responsible decisions—unless one is prepared to admit that "might makes right" is an ethical theory.

A duty-based search for the absolutely right course of action to pursue disintegrates in the presence of complexities beyond the reach of assertions about duty. In a word, the standard objections on the basis of competing claims and correlative duties simply apply a fortiori.

Which workers should be given preference when layoffs are required? Those with seniority or those with protected group status, e.g., women or minorities? To whom are persons on various levels of management more responsible—investors, customers, suppliers, employers, or the community or communities in which their plants are located? Or perhaps the governmental entities that have favored the company with direct or indirect subsidies? What import should or can be given to individuals who would be seriously affected by a given decision but who are represented by no organizational structure that has direct input into or on the level of the relevant decision-making process? Even assuming the existence of an effective world government, which part of the world's population should be favored, and on the basis of what considerations? Developed or developing nations? One developed nation more than another? The country with the largest percentage of unemployed, or the largest number of unemployed, or the fewest robots? Or, just to make the madness complete, might robots themselves have rights, or even rights prior to those of humans—some humans, or all humans?

What is lacking is nothing less than the Marxist ideal of an international proletariat. Language barriers aside, this sort of shared community of interest is not likely to come about until the plight of the economically dispensable electronics worker in Asia and that of the robot-replaced automotive worker in Detroit are seen to be interrelated and equally important. Avowed Communists have failed to show that such solidarity is attainable without exploitation. But non-Communists, or capitalists, have done little better. That does not mean, however, that it is an ideal beyond human capability.

Notes

1. See Langdon B. Winner, *Autonomous Technology*, Cambridge, Mass.: MIT Press, 1977; John Cohen, *Human Robots in Myth and Science*, New York: Allen & Unwin, 1967.

2. See George Terborgh, *Automation Hysteria*, New York: Norton, 1966; Henry Elsner, Jr., *Technocrats: Prophets of Automation*, New York: Syracuse Univ. Press, 1967.

3. See Alvin Toffler, *The Third Wave*, New York: Morrow, 1980; G. Harry Stine, *The Third Industrial Revolution*, New York: Putnam, 1975.

4. Jasia Reichardt, *Robots: Fact, Fiction, and Prediction*, New York: Penguin, 1978, p. 120 (see also for discussion of the definition of a robot).

5. Desmond Smith, "The Robots (Beep, Click) Are Coming," *Pan Am Clipper*, April 1981; Ed Janicki, "Is There a Robot in Your Future?" *The Indianapolis Star Magazine*, Nov. 22, 1981.

6. "Russian Robots Run to Catch Up," *Business Week*, August 17, 1981.

7. "The Push for Dominance in Robotics Gains Momentum," *Business Week*, December 14, 1981.

8. Smith, *op cit.* See also *Metalworkers and New Technology: Results of IMF Questionnaire on Industrial Robots*, Geneva, Switzerland: IMF Document 81-13, 1981, pp. 37–38.

9. Reichardt, *op cit.* p. 138.

10. "Racing to Breed the Next Generation," *Business Week*, June 9, 1980.

11. "High Technology: Wave of the future or a market flash in the pan?" *Business Week*, November 10, 1980 (chart on "The Coming Impact of Microelectronics").

12. Responding to a survey conducted by Carnegie-Mellon University graduate students, users and prospective users of robots "*overwhelmingly* ranked efforts to reduce labor cost as their main motivation for installing robots. Current trade journal articles also give this as the primary motivation." *The Impacts of Robotics on the Workforce and Workplace*, Department of Engineering and Public Policy and Department of Humanities and Social Science, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 1981.

13. "Racing to Breed the Next Generation," *op. cit.*, 76.

14. "GM's Ambitious Plan to Employ Robots," *Business Week*, March 16, 1981.

15. "Fanuc Edges Closer to a Robot-Run Plant," *Business Week*, November 24, 1980. See also David Fleischer, "Robot-Built Robots," *Science Digest*, Dec. 1981.

16. GM's Ambitious Plan . . . ," *op. cit.*; Harley Shaiken, "The Brave New World of Work in Auto," *In These Times*, September 19–25, 1979.

17. "How Robots are Cutting Costs for GE," *Business Week*, June 9, 1980.

18. "General Electric: The Financial Wizards Switch Back to Technology," *Business Week*, March 16, 1981.

19. "Robots Join the Labor Force," *Business Week*, June 9, 1980.

20. "GE Is About to Take a Big Step in Robotics," *Business Week*, March 8, 1982.

21. Personal communication, Geary Soska, Director of Application Engineering, Cybotech, Indianapolis, Indiana.

22. "The Speedup in Automation," *Business Week*, August 3, 1981.

23. "Revamping Air Traffic Control," *Business Week*, January 18, 1982.

24. Habib Boulares and Francoise Hubscher, "La Technologie et Nous," *Jeune Afrique*, August 13 and 20, 1980.

25. "A Changing Work Force Poses Challenges," *Business Week* Special Issue: Japan's Strategy for the 80's, December 14, 1981.