Economics

About 7,000 children between the ages of 5 and 14 have no time for school because they work full time manufacturing soccer balls.

—http://www.cnn.com/world

[It is estimated] that up to 10% of U.S. farm laborers are enslaved... "A penny more per taco could translate into twice what pickers now earn for tomatoes."

—*National Geographic Magazine*, September 2003

What engineers can accomplish never ceases to amaze me. When I set up a new printer or peer inside a DVD player, I find it difficult to imagine the steps involved in bringing such commercial technology to my home at such low cost. I suppose that the cost of engineering probably doesn't contribute too much to the final price, having been spread over many thousands of copies. In fact, I imagine that the engineering value and economy of scale are so great that all expenses and profits related to shipping, retailing, advertising, and other functions are covered by the modest sum that I paid for the item. Cheaper goods mean greater wealth, I think to myself, and I feel that engineering raises the standard of living for everyone.

Some machines that engineers create are expensive, but they may be so effective in what they deliver that their cost is warranted. I watch a bulldozer leveling a field of dirt, and it finishes in a day. What is the person-equivalent, I wonder, of one operator and one machine? I once moved 22 cubic yards of dirt, and it took me a week. That one machine could do it in 10 minutes. And I'm sure that the bulldozer operator is less tired at the end of the day than I was after a half hour of manual labor.

But economics is a complicated business. If there were no earth-moving machines, people might be hired to move the dirt manually. So, does a bulldozer have a human cost in destroying jobs? Yes, but I reassure myself by making the value judgment that moving dirt is not a "good" job, so it doesn't matter, and by guessing that we all benefit from the money saved. Makes sense.

Automation has the same effect. We design machines that do work that people might otherwise do, displacing them from jobs. What jobs? That depends on economics. If using a machine costs less than the labor—which may include the cost of health insurance—then we build it and sell it. If the job is especially dangerous, such as removing nuclear waste, then "cost is no object!" and sophisticated robots become economically feasible.

Our control engineering accomplishments eliminate jobs that can be profitably replaced by machines. If we have the engineering tools and technology to design machines that are reliable and maintainable within the economics of the application, then we displace jobs with those machines. We feel satisfaction when those machines protect people from jobs that are stifling and hazardous while creating new jobs that are safer and more satisfying. It takes fewer people to design and fix the machines, we tell ourselves, but those jobs are more desirable than the jobs displaced by the machines.

But there are limitations to our abilities as engineers. If we could design economically profitable machines that could manufacture shoes and clothes at low cost, would entire industries have left for faraway locations where labor is incomprehensibly inexpensive? If we could design machines that could gently

pull tomatoes off a vine, would workers have to stoop over plants in hot fields for minimal wages? If a machine could sew the cover on a soccer ball, would children be exploited to do the work?

The problem is that humans are excellent controllers. With eyesight for navigation and feedback, innumerable force sensors, hearing for vibration sensing and communication, processing for problem solving that puts our best computers to shame, and more mechanical degrees of freedom than you can count, human workers are just too good at competing with machines in many venues.

So, in an economic system, humans get paid to do those things that machines cannot do. A robot cannot fix or design another robot, nor can it, except (perhaps) at astronomical cost, pick a tomato or sew the cover on a soccer ball. Furthermore, except in utopian visions of the future, there will always be jobs that no machine can economically perform. Unfortunately, the wages that are paid for a job that a machine cannot do profitably are often as much a function of political control as they are of supply and demand.

As control engineers, we develop automation that creates wealth and relieves humans from jobs that are numbing and dangerous. But we have failed when we are unable to develop technology that achieves these goals, and those jobs are instead transferred to a place where repetition and harm are more tolerated for whatever reason. It is my hope that the low cost of what I buy is the result of what we as engineers have accomplished in our profession, rather than the shameful alternative.

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