Control and Sustainability

I don't know many control engineers and technologists who are also environmental activists, and I have often wondered why. Perhaps they have no time for such "extracurricular" activities. But maybe there are other reasons too. Here are some of my own musings on this issue.

SUSTAINABILITY AND TECHNOLOGY

A major motivation for caring for the environment is to ensure its *sustainability*. What exactly does this word mean? According to [1],

> In ecology, sustainability (from sustain and ability) is the property of biological systems to remain diverse and productive indefinitely. Long-lived and healthy wetlands and forests are examples of sustainable biological systems. In more general terms, sustainability is the endurance of systems and processes. The organizing principle for sustainability is sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture.

Reference [2] defines *generous sustainability* as

> (1) Creating societies that leave sufficient natural resources for future human generations to live good lives; and (2) sharing the landscape generously with nonhuman beings.

Sustainability is a noble goal. However, there are salient contrasts between sustainability and technology worth highlighting that might explain why some technologists have trouble relating to sustainability as a goal. First, issues in sustainability often involve *slow* timescales, while technology often involves *fast* timescales. Second, sustainability is an idea that is inherently cautious, perhaps even associated with *pessimism* about the future. On the other hand, technology is often associated with *optimism* about the future.

To illustrate this contrast in timescales, consider population growth, an issue of interest to environmentalists. Over the past 100 years, the immigrant population in the United States has increased threefold [2]. For a period of 300 years starting in 1750, the world population was estimated to grow approximately tenfold [3]. Contrast these numbers with of the rate of growth in technology, as described by Moore's law. The transistor count in microprocessors has increased by a factor of 10^6 over 40 years [4]. Over 30 years, hard-drive costs per gigabyte has decreased by a factor of 10^7 [5]. Finally, over the past 100 years, computer power has increased by a factor of 10^{18} [6]. The contrast between these numbers and those of population growth is staggering, to say the least. Much of this sustained growth can be attributed to disruptive technologies.

To illustrate the attitude of technologists toward the future, consider the following quotes from well-known technology commentators [7], [8]:

- "I'm not saying we don't have our set of problems—climate crisis, species extinction, water and energy shortage—we surely do. [But] ultimately we knock them down."
- "If we could convert 0.03 percent of the sunlight that falls on the earth into energy, we could meet all of our projected needs for 2030."

Indeed, the history of technology imputes great optimism about the future.

Yet the waters of the future remain deep and murky. According to another great technologist of our time, Bill Gates, "We always overestimate the change that will occur in the next two years" [9]. To illustrate this overestimation, consider this optimistic and rather familiar quote about PCs in the future [10]:

> Whether you have a PC on your desk in 10 to 15 years will be a matter of choice, not necessity. If you do, it will be vastly more powerful than your current system, thanks to advances in nanotechnology.

The IEEE Control Systems Society Executive Committee members and editors hard at work, April 2017.

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Can we trust this prediction? To answer this question, consider the following from the *same* publication making a prediction in 1987 about what PCs would be like in 1998 [11]: "When you walk into an office in 1998, the PC will sense your presence, switch itself on, and promptly deliver your overnight e-mail, sorted in order of importance."

Even today, almost two decades after 1998, the PC still doesn't sense presence and switch itself on! How could we get this so wrong?

HOW TO THINK ABOUT THE FUTURE

One way to think about the future is in terms of its risks and how to manage them. Risk is the potential that a chosen action or activity will lead to an undesirable outcome. Risk should be familiar to engineers and technologists because it goes hand in hand

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with innovation. Indeed, risks are taken because of the associated potential benefits. Risk *management* is ultimately a problem of control and optimization.

To illustrate how risk is associated with technology, consider the risks associated with disruptive innovations. According to [12],

> A *disruptive innovation* is an innovation that helps create a new market and value network, and eventually goes on to disrupt an existing market and value network (over a few years or decades), displacing an earlier technology.

Disruptive events in technology are not always beneficial. In 2011, a flood in Thailand crippled hard-drive suppliers, causing a marked increase in prices. This disruptive event had a negative outcome lasting at least two years [13]:

> Western Digital's flood-related costs were estimated at between US$225–$275 million, however, an insurance claim of US$50 million for property damage, and another claim for business interruption would help lower the net impact. As a result, most hard disk drive prices almost doubled globally, which took approximately two years to recover.

Another example of risk associated with technology is that fast timescales in technology are a double-edged sword. On the one hand, new technologies are quickly released in the marketplace, leading to rapid improvements in our quality of life. On the other hand, these new technologies lead to rapidly growing threats to our environment. For example, consider the following quote on the growth in electronics waste [14]: "The United Nations estimates that there's about 85 billion pounds a year of electronics waste that gets discarded around the world each and every year."

In fact, for every technology utopian touting the great benefits of technology for the future, there is a technology dystopian proclaiming the damage that technology has done and will continue to do to the world, illustrated by the following quotes [15], [16]:

» "Suddenly, we humans—a recently arrived species, no longer subject to the checks and balances inherent in nature—have grown in population, technology, and intelligence to a position of terrible power."

» "We transform the world, but we don't remember it. We adjust our baseline to the new level, and we don't recall what was there."

THE ROLE OF CONTROL

The systems and control community has a role to play in influencing the future: treat the problem of managing risk as a control and optimization one. Surely, this group has the right tools and thinking to help solve this dilemma. Regarding climate change, "We've got the science, we've had the debate. The moral imperative is on the table. Great creativity is needed to take it all, make it simple and sharp. To make it connect. To make it make people want to act" [17]. In treating risk management as an optimization problem, what objective function should we use? This is a difficult question. Whatever the answer, ethical considerations must be brought to bear. At a minimum, people should take responsibility for their actions, in response to this indictment from [18]: "Today scientists, technologists, businessmen, engineers don't have any personal responsibility for the consequences of their actions." Indeed, according to [19],

> Let's forget your environmental footprint. Let's think about your ethical footprint. What good is it to build a zero-carbon, energy efficient complex, when the labor producing this architectural gem is unethical at best?

PARTING THOUGHTS

It is easy for technologists to be optimistic about the future, and I am not suggesting we should be otherwise. However, our optimism must be *scrupulous*, to use a term popularized by [20]. This means managing risks, which must account for ethical concerns. It all boils down to solving a difficult control and optimization problem. I end by completing an earlier quote from Bill Gates, which is a call to action of sorts [9]:

> We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. Don't let yourself be lulled into inaction.

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Edwin K.P. Chong