The Yin and the Yang of Control

Under Heaven all can see beauty as
beauty only because there is ugliness
All can know good as good only
because there is evil
. . .
Work is done, then forgotten
Therefore, it lasts forever

—Tao Te Ching

What is the distinguishing feature of all human activity? I believe it is the potential for both good and bad. I have no proof of this statement but, at the same time, I have not found a counterexample. The list of supporting examples, on the other hand, is a long one. Automobiles enhance our lives by providing mobility and personal freedom, but they pollute the environment and increase our dependence on foreign oil. Religion satisfies a basic human need for spiritual guidance but is also used as an excuse for intolerance and persecution. The development of pain-killing drugs and anesthetics has relieved much human suffering and made life-saving surgery possible but has also created an epidemic of drug abuse. Social welfare programs provide a safety net to protect the most vulnerable members of society but have been accused of leading to the disintegration of families. The list goes on and on.

Within the realm of technology, this potential for good and bad is closely related to the oft-cited law of unintended consequences. For example, the advent of air bags has led to an increase in unsafe driving behavior. The invention of antitheft devices for automobiles has led to an increase in carjacking. A rather surprising example is the discovery that traffic problems may actually be exacerbated by the construction of new freeways. Even seemingly innocuous acts can lead to some bizarre consequences. One summer during my graduate student days, I worked for a small operations research group at a certain Midwestern government facility. During the energy crisis in the mid-1970s, the U.S. government imposed a regulation that no federal building could be cooled below 78 °F. This particular facility was constructed over some large underground caverns where the air temperature was a cool 55 °F yearround. Air from these caverns was circulated through the buildings to cool them in the summer. Free energy! Well, to comply with the new regulation, the air had to be heated to 78 °F before being circulated. And they did it!

Opposing Notions

In eastern philosophy, the notions of yin and yang capture the essence of opposing principles and phenomena, such as heaven, the sun, heat, and light in the case of yang, and Earth, the moon, cold, and darkness in the case of yin. Each phenomenon produces its opposite: Heaven creates the idea of material being, the Earth produces its material form, and so on. Moreover, the creation of yin from yang and yang from yin is cyclical. All opposite states—health and sickness, wealth and poverty, power and submission—can be explained by a temporary dominance of one principle over the other. Moreover, nothing is purely yin or purely yang. Rather, each thing contains the essence of both. For example, within sickness are the seeds of health, within submission are the seeds of power. This potential is called "presence in absence."

What about control engineering? Since my basic thesis is that all human activity carries with it the potential for both good and bad, it should come as no surprise that control engineering fares no better (or no worse) in this regard. For example, control theory is used to create smart weapons that can pinpoint and destroy targets without collateral damage. As a consequence, there may be fewer restraints on the use of such weapons. Factory automation increases productivity but eliminates jobs in the process, and so on.

As the pace of technology increases, will the natural oscillations between the yin and the yang in control engineering grow unbounded and lead to instability? Or by recognizing the inevitability of unintended consequences, can we optimize the intended (good) consequences and minimize those unintended (bad) consequences? I have two simple suggestions on how to proceed.

Suggestions

First, we can carefully choose the problems we work on with an eye toward their benefit to society. Notable examples abound, including the robotic land mine detection project of Prof. Furuta and Prof. Hirose in Japan and the Autonomous Ocean Sampling Network project, the con-

trol portion of which is led by Prof. Naomi Leonard at Princeton. Another example is nuclear power generation. As world oil reserves dwindle, there will be increasing demand for nuclear energy. At least in the United States, no new nuclear power plants have been built in more than two decades, and none are planned for the foreseeable future. But this lack of construction means that the control systems on these power plants are often more than two decades old. Simply by upgrading the control systems, both the useful life and the efficiency of these power plants can be greatly enhanced. The yang of nuclear power leads, of course, to the yin of nuclear waste. Perhaps control technology can be applied to develop improved methods for safe transportation and disposal of nuclear waste. There are plenty of other control problems that are both intellectually challenging and highly relevant to society.

Second, we can demand excellence in everything we do. As a popular song from the 1940s says, "you've got to accentuate the positive, eliminate the negative, latch on to the affirmative, and don't mess with Mr. In-Between." The future demands no less of us. The 21st century is ushering in a brave new world where control engineering will play a major role in the life sciences, in security for networked and embedded systems, in nanotechnology, and in a host of other applications to which control has not yet been applied. In these applications, control can have life-saving consequences if done right and life-threatening consequences if done poorly. There will be unintended consequences of advances in control engineering, especially from applications in disruptive technologies. By demanding excellence, we can minimize negative impacts. Nothing less will suffice.

Society News

I just returned from the IEEE Technical Activities Board (TAB) meetings in San Francisco. The TAB consists of TAB officers, Society and Council presidents, Division directors, and a few others. Most CSS members are unaware of TAB activities, but there are a number of decisions made by TAB that have a direct bearing on Society activities, such as the approval of budget processes, new journals and magazines, and the creation of new Societies and Councils. Therefore, I thought I'd update you on some of the recent goings on within TAB.

Systems Engineering Council

Under discussion within TAB is a proposal for a IEEE Systems Council, whose charter would be to promote collaboration among IEEE Societies whose interests overlap systems engineering: the IEEE Control Systems Society (CSS), the IEEE Computer Society, the IEEE Systems, Man, and Cybernetics Society, the IEEE Robotics and Automation Society, and others. Many CSS members have a strong interest in systems engineering. Industrial research these days is more and more focused on problems of systems integration as engineering systems become larger and more complex. I encourage everyone to read the report from the U.S. National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," which discusses the future role of systems engineering in important societal problems and, more importantly for us, the role of control in systems engineering. I believe that the CSS can and will play a major role in this area and I intend to support the proposal for a Systems Council within IEEE.

Financials

After several years of deficits, the IEEE is again in the black with reserves back up to their year 2000 level. This is good news for the Society as the IEEE had been taxing Society revenues for several years to balance the budget. Our Society reserves, while not at the level of the late 1990s, are back to healthy levels. Overall, the financial health of the Society is excellent.

Open Access and Google Scholar

The majority of IEEE revenue derives from intellectual property in the form of magazines, journals, and conference proceedings published by member Societies, which are now available online through IEEE *Xplore*. The advent of open access journals, where authors pay a fixed fee to publish a paper that is then available at no cost online, poses a strong challenge to the current financial health of the IEEE. A potentially more serious threat comes from Google Scholar, which will not only find papers on IEEE *Xplore* that can be downloaded for a fee, but which will also find the same paper on the authors' own Web page if they post it there. Since the CSS derives revenue from IEEE *Xplore* downloads of CSS publications, this capability also impacts the financial health of our Society. The IEEE is looking for ways to increase revenues from sources other than publications, such as online short courses, to counter the possible loss of revenue from open access journals and Google Scholar.

Membership

The membership of the CSS, as well as most other Societies within the IEEE, continues to decline a few percentage points per year. A recent membership survey conducted by the IEEE indicated that the availability of Society journals through IEEE *Xplore* is a large factor in this decline. Access to IEEE *Xplore* through a university or employer is a disincentive to joining the IEEE or renewing one's membership. This is another perfect example of an unintended consequence resulting from a disruptive technology.

As always, I look forward to receiving your comments at mspong@uiuc.edu.

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