Crazy Clocks: Counterintuitive Consequences of “Intelligent” Automation

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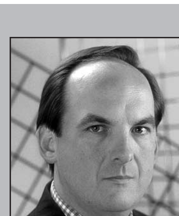
Human error is a widely recognized problem,[1–4] and there are at least two complementary paths to error mitigation. One approach aims to reduce error by changing the design of systems and products to make them fit human capabilities and limitations. Another approach aims to remove human error (and human involvement) altogether by automation, sometimes including intelligent systems. The latter approach might seem preferable. After all, if no human is involved, how can there be any human error?

Both paths have merit. However, the automatization path might be so tempting that researchers might not realize the new, counterintuitive problems this approach can create. Recent attempts to eliminate human error in programming a VCR provide a poignant example of this concern.[5,6]

Setting VCR clocks automatically

The flashing 12:00 that appears on VCRs in many households is a prototypical example of an endemic problem in the information age—people find technology to be too complex. Some VCR designers thought they could overcome this problem by trying to completely eliminate human involvement. They designed a clock that would automatically be set by a timing signal that accompanied the transmission of a TV program. The idea seems impervious; if people don’t need to set the time, human error should be completely eliminated.





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Unfortunately, this turned out not to be true. In one case, thousands of people in the San Jose, California, area noticed that the self-setting clocks on their “advanced” VCRs were running 24 minutes fast. In another case, clocks in other parts of the country were off by one, two, or even three hours.

Eventually, several root causes were discovered, but to understand them, you have to understand how these “autoclocks” work. An electronic circuit scans the TV channels in increasing order, beginning with channel 2. As the circuit scans, it searches for a digital timing signal that most US Public Broadcasting System stations emit. Once the circuit finds such a signal, it stops at that channel and uses the signal to automatically set the clock’s time.

In the San Jose case, a PBS station there did not have a chief engineer on duty for a year. During that period, the timing signal had become 24 minutes fast. The new chief engineer did not know that this timing signal existed, much less that it needed regular monitoring. Moreover, the station had no procedure or documentation to tell workers that maintenance was important to ensure the timing signal’s accuracy. In fact, even when the newly hired chief engineer found out about the missing signal, he did not know what equipment in his station generated it. Eventually, after consulting other technical experts, the chief engineer located the relevant equipment and synchronized the timing signal. Thousands of VCR clocks in the area finally switched from being 24 minutes fast to showing the correct time. Their users must have been pleased, albeit surprised.

In the other case, the Fox network’s stations had been including a timing signal on the feeds broadcast from its Los Angeles station. This signal was the same type that PBS stations used; VCRs with the autoclock feature could recognize it. Several Fox affiliates across the country failed to modify the signal to match their time zone, so the Los Angeles timing signal was being broadcast from several locations across the country. Furthermore, in many places, Fox broadcasts on a lower-numbered channel than PBS. In these cases, the self-setting VCRs would detect the Fox signal, lock onto it, and use it to set the clock,

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resulting in an erroneous time display.

Consider the hypothetical example of an East Coast Fox affiliate broadcasting on channel 5 and a local PBS station broadcasting on channel 13. The VCR autoclock would begin searching with channel 2, find a timing signal on channel 5, stop its search there, and then use that signal to set the clock—to Los Angeles time. The autoclock would never get to the PBS station, which is broadcasting the correct timing signal. So, an East Coast VCR owner would have his or her VCR clock automatically (and mysteriously) set to West Coast time, causing a discrepancy of three hours. VCR users in the mountain and central time zones experienced analogous problems, with respective discrepancies of one and two hours. Engineers took about a year to uncover this convoluted and intricate set of interactions.

After Tekla Perry reported this phenomenon in *IEEE Spectrum*,[5] many readers wrote to complain of their frustrating experiences with self-setting VCRs.[6] One person reported that the time on his VCR would change during the day in a seemingly random way. Sometimes, the time was accurate. Then, it would be wrong. And then, it would be accurate again. The cause might be that when some programs were taped for later broadcast, the timing signal was not removed. Thus, when the program was televised, the timing signal was for the time the program was first taped, not the current time. The VCR autoclock dutifully changed the displayed time accordingly. After the program, the station broadcast an accurate timing signal again, and the clock returned to the proper time.

A person on the East Coast reported that his VCR was two hours fast. So, he fooled the VCR into thinking that he lived in the mountain time zone, thereby canceling out the discrepancy. A few weeks later, his local station corrected the timing-signal problem, and his VCR clock went to being two hours slow. The person fixed the problem by resetting the time back to the eastern time zone.

Another person bought a new VCR and a new TV at the same time, both with self-setting clocks. However, the two autoclocks didn't work the same way. So, they each displayed a different time. Being an engineer, this person tried several ways to get the two clocks to agree, but all attempts were futile.

Several people who reported their frustrating experiences said they have disabled their VCR autoclocks and have gone back to setting the time manually. The conclusion is clear: "VCR autoclocks cannot be fully trusted."[6] Fortunately, VCRs are not life-threatening, safety-critical systems.

Implications

These examples show that trying to remove human involvement by automation or intelligent systems can introduce new problems. Moreover, these problems are counterintuitive because you might think that by completely removing user involvement, errors could not possibly occur. You can see the fallacy of this belief by adopting a systems approach[1,7] that provides a holistic, integrated view of the technical, human, and organizational infrastructure that is required to support the proper functioning of the autoclocks. From this perspective, you can clearly see that automation does not necessarily eliminate human error because it does not eliminate human involvement. It merely shifts the burden from frontline workers to people who work in a different part of the system. In the case of VCRs, the autoclock designers and the engineers at the local television stations have to continually ensure that the technical infrastructure is operating correctly so that the autoclocks function as intended. People are still involved.

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There are good reasons to believe that applications of intelligent technology are no different. There are many good reasons to believe that applications of technology in more complex and safety-critical systems (for example, medical, nuclear, aviation, and petrochemical) are also no different.

For example, some hospitals might try to eliminate drug–drug interactions by creating a fully automated system that uses the Internet to connect the hospital information system to a centralized database containing a list of dangerous interactions. This system eliminates physician involvement but still relies on the people who operate and maintain the hospital information system, the hospital's Internet service provider, and the centralized database. A lack of systems integration in this sociotechnical infrastructure can result in errors (for example, if the database is not updated). Moreover, because the physicians will be accustomed to letting the automation do all the work, they might not be vigilant and notice a problem of this type until patient safety has been threatened or compromised. Indeed, in one case, automated monitoring of physician ordering entry reduced the overall number of nonintercepted serious medication errors but doubled the number of such errors for drug problems that the computer database did not address.[8]

Automation, including the incorporation of intelligent systems, plays an important role in improving safety and productivity. However, trying to eliminate human involvement through automation is not a foolproof solution. Saying that a problem has a technological fix and that the application of intelligent technology will be a real or sure-fire fix might serve merely to place you on the well-known path that is paved with good intentions. Only by adopting a holistic, systems approach can we make the most of what technology has to offer to people, and thus to society.

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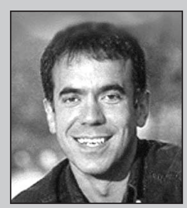

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