Editorial: Human Factors in Embedded Computing

I recently attended a talk on "Human Factors" in Cyber Security. It dawned on me that we have not published a special issue on human factors in embedded computing or related topics. Neither do I see many papers on the confluence of embedded computing and human-computer interface or human factors.

A search on Google did not yield many works in this field. I found only a handful of papers that considered human prosthetics, assistive technologies, and one paper on cognitive behavioral changes induced by ubiquitous embedded computing in our daily lives.

However, considering that embedded computing is now so pervasive in our daily lives, the human-computer interface should be an important aspect of research. I know that "design programs" at several universities pay considerable attention to human interface with technology and devices, but that does not seem to operate in a tight cycle of feedback. Design experts work after the functionality has been implemented, or before, but a tight feedback loop would make for interesting research problems. Smart phone screen designs, form factor designs, and look and feel of apps are given tremendous importance by companies that manufacture them. For medical devices, such as an insulin pump, or a smart watch, a lot of these factors are considered. Today's entertainment systems, such as smart TV, and home-assistive devices, such as Alexa, usher in new ways of interacting with computation but also influence our behavior and daily routine. Large-scale ensemble embedded systems, such as IoT for home or factory automation and industrial control systems, need console-based monitoring and human-in-the-loop control.

Human-in-the-loop computation touches several of the "14 grand engineering challenges for the 21st Century" posed by the National Academy of Engineering of the United States. For example, the problems of personalized learning, enhanced virtual reality, and advanced health informatics are some of the problems that would require convergence of embedded computing and human-computer interaction. Industrial control systems are good examples of human-in-the-loop control, where instead of an autonomous closed-loop control, we have human operators receiving assistance from the state estimator, and other relevant computation, and making human decisions to actuate control. We see this in power system control centers. The issues of cognitive overload of the operators and better interpretability of large-scale real-time data for human operators to make informed decisions efficiently are two very important issues.

Humans in charge of steering the control or computation presents possibilities of human mistakes, which are cognitive or behavioral and not based on software/hardware functional bugs or cyberattacks on autonomous systems. Social engineering of humans is an example of a cyberattack that could leave an industrial control system exposed. The anecdote of how STUXNET got inside an air-gapped secure facility is a glaring example of social engineering that led to a complex cyberattack on an industrial control system. Human habits of cyber hygiene will play an important role in securing our computing and critical infrastructure.

If one believes that computing—especially embedded computing—is to enhance automation to relieve humans from mundane and repetitive work, or for compute intensive work, then it is not a one-way street. The fact that our reliance on embedded computing is increasing fast means the human factors in operating these systems will be far more important than before. Further,

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behavioral and social changes induced by this reliance on technology will be another important issue to be considered.

My hope is that some of the editors and readers of this journal will take this up, propose a special issue on human factors in embedded computing, and bring together researchers in these fields to not only publish new papers but also initiate the collaborative efforts that may need a boost.

With this issue, we are starting Volume 18 of ACM TECS. As of the last volume, we are publishing six print issues per year. This issue is the first of six issues to be published as Volume 18.

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