The State of Cognitive Systems Engineering

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The widespread introduction of the personal computer, beginning about 1970, helped spawn the field of inquiry called *cognitive engineering*, which concerns itself with such things as interface design and user friendliness.

Since then, this field has taught us many important things, including two major lessons.

First, the road to user-hostile systems is paved with designers' user-centered intentions. Even smart, clever, well-intentioned people can build fragile, hostile devices that force the human to adapt and build local kludges and workarounds. Worse still, even if you are aware of this trap, you will still fall into it.

Second, technology developers must strive to build truly human-centered systems. Machines should adapt to people, not the other way around. Machines should empower people. The process of designing machines should leverage what we know about human cognitive, perceptual, and collaborative skills.

Time to rethink

We're in a new ballgame, in which the modern "sociotechnical" workplace is characterized by changing collaborative mixes of humans and machines. Advances in technology have opened new horizons that are changing the nature of work and education, including distance learning, distance collaboration, training support, and performance support.[1–3]

Consider, for example, the notion from human factors engineering of *task analysis*: you can decompose jobs into invariant linear or tree-like sequences of actions (and some cognitions). This notion has a long history, dating to the applied psychological research in Europe dubbed *psychotechnics* in the late 1800s. (This notion of task differs from the AI notion of "generic tasks."[4])

Studies of the modern workplace suggest that significant problems can arise when you design systems based on a decomposition of tasks into invariant sequences of prescribed steps. Sometimes, people might appear to be conducting linear sequences of actions, when they are actually engaging in context-sensitive, knowledge-driven choices among alternative actions.[5,6] Would loss of the uplink to the weather radar keep a forecaster from crafting a forecast? No, the forecaster can work around it because knowledge permits the creation of alternative paths to the goal. When you are forced to adapt, kicking and screaming, to a new software upgrade and are frustrated by changes in functionality, are you totally paralyzed? No, you can craft a workaround.

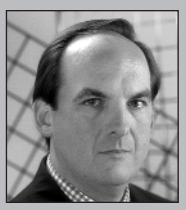
The point is not that something is inherently wrong about the notion of a task as an expression of a particular goal, but that task analysis as it has been applied can sometimes be limiting. When regularly occurring sequences are regarded as invariant and therefore predefined, systems designed on this basis can run a substantial risk of being flawed. Specifically, you can expect them to lead to fragilities, hostilities, and automation surprises.[3,7] In short, they might not be human-centered.

Over the past decade, research activities have converged on new notions of "cognitive field research" and new frameworks that point toward methodologies for crafting human-centered systems.[8–13]

Understanding

Research over the past decade has led to





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- Knowledge about the development of proficiency and the acquisition of skill leading to the achievement of expertise[13–17]
- Effective methodologies for eliciting and preserving the knowledge of domain practitioners[18,19]
- Clear ideas of how to describe the reasoning and decision-making skills of experts[20–22]

We also know the strengths and weakness of alternative methods and how to fit the methods to particular practice domains and research goals.[23–24]

> Converging research and ideas from the cognitive, social, and computational sciences will lead to a concrete road map guiding the creation of human-centered technologies.

Application

- We are learning how to train people to become "expert apprentices"—that is, empowering them to enter into a domain or organization, arrive at a rich empirical understanding of work practice, and perceive the "true work" that must be accomplished.[13] This supports the process of revolutionary design.
- We know how to go from models of expert knowledge and reasoning to revolutionary designs for systems to display information and support both the learner and the practitioner.[25]

Where the rubber meets the road

Analyses of technology and its impacts have lead to an understanding of what it means for technology to be truly human-centered.[26–29] Converging research and ideas from the cognitive, social, and computational sciences will lead to a concrete road map guiding the creation of human-centered technologies. However, to reach this destination, system designers must refuse to cave in to penny-wise, short-term thinking in system development. They also must have zero tolerance for user-hostile systems. Who will step up to bat? ■

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