Human Factors in Control

J. Brooks*[1], K. Siu†[2], and A. Tharanathan‡[3]

[1]Real-Time Optimization and Controls Lab, GE Global Research
[2]Model Based Controls Lab, GE Global Research
[3]Human Factors Center of Excellence, Honeywell Advanced Technology Labs

Topic

The propose of this workshop is to introduce the broader controls community to theoretical frameworks of human performance (from human factors, applied psychology, and cognitive science) which are relevant to the interaction between humans and the systems designed around them as well as highlight relevant, active application and research areas. The selected talks and speakers are a blend of theory from academia as well as current applications in industry. This workshop directly supports the conference themes and the public lecture by Professor David Mindell on "How We Interact with Robots, Feedback Loops, and Autonomous Systems: Historical Perspectives and a Look Forward."

All control systems are designed to meet the needs perceived by humans as well as interact with humans on some level. As control systems become more inclusive of complete systems, human factors will become an increasingly important consideration in the design and analysis of control strategies. All three conference themes — societal challenges for control, sustainability, and smart healthcare systems — demonstrate both the increasing scope of controls and imply the increasing importance of understanding the human element in future systems.

This workshop will be beneficial for systems engineers (both in academia and industry) working on control systems and/or complex systems with significant human interaction and perception requirements as well as graduate students in relevant areas. These areas include human performance and intent modeling, human supervisory control, interface design, manual control, human-in-the-loop systems, and perception of optimality by operator.

Format: Full-day (1)

*brooksja@ge.com
†siu@ge.com
‡anand.tharanathan@honeywell.com

Schedule

Time	Speaker	Title
8.30-8:45	–	Welcome and Introductions
8.45-9:45	Mica Endsley	Situation Awareness Research and Design in Complex Systems
9.45-10:00	–	Coffee Break
10.00-11:00	Stephanie Guerlain	User Interface and Decisions Support Concepts for Supervisory Control
11.00-12:00	Ling Rothrock	Judgement and Decision Making in Human-Machine Systems
12.00-1:00	–	Lunch (on your own)
1:00-2:00	So Young Kim	Improving Reliability Through Enhanced Operator Effectiveness: Building State-Of-The-Art Operator Human-Machine Interface
2:00-3:00	Anand Tharanathan	Functional Versus Schematic Overview Displays: Impact on Operator Situation Awareness in Process Monitoring
3:00-3:30	–	Coffee Break
3:30-4:30	All	Panel Discussion

Abstracts

Situation Awareness Research and Design: The biggest challenge within most industries and the most likely cause of an accident receives the label of human error. In fact, the human operator is frequently not the real cause of these errors, but merely the final participant over the inherent problems and difficulties in the technologies they manage. The operator is usually the one who must bring all the technologies together and overcome whatever failures and inefficiencies exist in the system to provide successful daily operations, but cannot always do so when enough problems converge. If we examine accidents in a wide variety of industries, we find that the operators have no difficulty in physically performing their tasks, and generally less difficulty in knowing what is the correct thing to do, but they continue to be stressed by the task of understanding of what is going on in the current situation. Developing and maintaining a high level of situation awareness is the most difficult part of many jobs.

Due to its importance and the significant challenge it poses, finding new ways of improving SA has become one of the major design drivers for the development of new systems. In this presentation, I will discuss the current state of research on situation awareness and its application to the design of systems for enhancing this important construct in individuals and in teams.

User Interface and Decision Support Concepts for Supervisory Control: One of the major hindrances to human performance is that we are to a large extent serial human information

processors (can only do one thing at a time), so because of this need to constantly switch our attention between tasks, and the limits of our short term and prospective memory, it is quite possible that intended actions get dropped or, if a task requires too many steps to perform (usually due to a poor user interface design) then we are unnecessarily burdening our human operators and adding risk to the operation. In this talk, I will show several examples of user interface designs and decision support techniques in supervisory control domains, such as petrochemical, nuclear power, aviation and military domains that transform what was an unnecessarily complex set of human information processing tasks into much simpler "direct' perceptual "pick-up" of key information at a glance or example of presenting "the right information at the right time". One of the best ways to get good design ideas is to see other design ideas. Thus, this will be a fast-paced set of examples and design strategies that will enable you to perhaps apply similar ideas to domains that you are working in.

Judgement and Decision Making in Human-Machine Systems: With the advancement of technology, the role of humans in human-machine systems has shifted more toward supervisory management. A major challenge in highly automated systems where humans are ultimately in control is the need for effective decision making in abnormal situations. A research paradigm will be presented to observe, measure, and analyze judgment decision making in real-time systems. Implications of existing research findings will be discussed.

Improving Reliability Through Enhanced Operator Effectiveness: Combined-cycle power plant industry continues to demand high plant performance: more flexible operating profiles that include frequent fast maneuvers of the plant machinery and processes that enable fast ramping and low turn down from full load. At the same time, these plants provide critical generating capacity to the grid; thereby, the challenge of maintaining highly-reliable power generation has increased. Because these plants undergo transient mode changes multiple times during a typical-day operation, the operator effectiveness, therefore, the effective operator HMI design become more critical than ever. Furthermore, the introduction of higher level of automation and decision support systems complicates the operator HMI design.

A research project was initiated to marshal new technologies to enhance the operator effectiveness in running a state-ofthe-art combined cycle plant. Human Factor Engineers and UI Designers developed new HMI design philosophy by compiling the latest UX research from diverse industry domains such as Power, Aviation, as well as Consumer Electronics, which, we validated with global power plant operation staff. The new design philosophy brought innovation in the operator HMI design. First, we leveraged progressive and leading-edge design qualities and executions from consumer electronics user experiences. Second, we executed lessons learned and research insights into an innovative design that differs significantly from the current industry practices.

This talk describes the process from the initial research to the final design philosophy in detail. First, it presents the preliminary research with third-party consultants. Then, the in-depth user research conducted with operations staffs in combined-cycle power plants is described. Finally, the design philosophy based on resulting UX principles and other research insights are presented with the next generation GE HMI concepts.

Functional Versus Schematic Overview Displays: It is important for console operators to maintain good situation awareness while monitoring process operations. A key component that helps operators achieve better situation awareness is how the information about the process is displayed on their console. Most oil and gas refineries still utilize traditional schematic

displays and connecting lines between equipments to present process information. In this study, we designed a functional layout for an overview display. This layout shows the same process parameters as a traditional schematic display, but in a different format. Eighteen plant operators viewed both displays to monitor a crude unit process and their situation awareness was measured. Results indicated that operators situation awareness was significantly higher when they monitored the process on a functional display compared with a schematic display. The implications of the findings for continuous process control will be discussed.

Presenter Biographical Sketches

Mica Endsley (SA Technologies) is President of *SA Technologies*, a cognitive engineering firm specializing in the analysis, design, measurement, and training of situation awareness in advanced systems, including the next generation of systems for aviation, air traffic control, medical, power, military operations, homeland security, and cyber-security. Dr. Endsley received a Ph.D. in Industrial and Systems Engineering from the University of Southern California. Prior to forming *SA Technologies*, she was a Visiting Associate Professor at MIT in the Department of Aeronautics and Astronautics and Associate Professor of Industrial Engineering at Texas Tech University. She has authored over 200 scientific articles on situation awareness, decision making, and automation. She is co-author of *Analysis and Measurement of Situation Awareness* and *Designing for Situation Awareness*. She is currently serving as President of the Human Factors and Ergonomics Society.

Stephanie Guerlain (Univ. of Virginia) joined the faculty at the University of Virginia in 1999. She has published over 40 technical publications on various aspects of cognitive systems engineering, focusing on decision support systems, data visualization, and computer-based training. Prior to joining the faculty, she was Principal Research Scientist at Honeywell Technology Center, working primarily on process control applications. She is a member of the IEEE Systems, Man and Cybernetics Society, the Cognitive Science Society, and the Human Factors and Ergonomics Society. She and her students have won 5 conference "best paper" awards and 1 journal "best paper" award. Stephanie specializes in the design of decision support systems, cognitive systems engineering, human-computer interaction and data visualization. She applies her research to medical, military, process control, and bioinformatics areas.

Ling Rothrock (Penn State Univ.) directs the Human Performance assessment and modeling (HPAM) laboratory. His research areas include human-in-the-loop discrete event simulations, display visualization, and human-machine performance evaluation. His simulation software has been used by the U.S. Navy for training and modeling. He has also been funded by the National Science Foundation to investigate decision strategies in dynamic tasks. He has published over 80 technical articles in the area and obtained over $3 million in external funding. Dr. Rothrock is an Associate Editor for the Institute of Electrical and Electronics Engineers (IEEE) Transactions on Systems, Man, and Cybernetics (Part A), a past president of the Computer and Information Systems Division of the Institute of Industrial Engineers and a senior member IEEE.

So Young Kim (GE Research) is a UX/Human Factors Researcher at the UX Innovation Lab in GE Global Research, located in Bay Area, CA. The UX Innovation Lab uncovers new, compelling user experiences for the industrial systems (in areas such as aviation, healthcare, energy, and transportation) enabled by deep user understanding and emerging natural user

interface technologies. She is responsible for user research, design, and validation as well as project management. So Young Kim received her Ph.D. from School of Aerospace Engineering at Georgia Tech, focused on Human-Automation Function Allocation.

Anand Tharanathan (Honeywell) is a Senior Scientist at Honeywell Advanced Technology Labs in Minneapolis. Anand received his Ph.D. in Experimental Psychology from Texas Tech University in 2008, with a specialization in visual performance and cognition. He has an undergraduate degree in Production Engineering and an MS degree in Industrial Engineering. Anand has extensive research experience in measuring and evaluating human performance, with implications for training, enhancing displays and human-automation systems. He is on the editorial board of *Ergonomics in Design* and *Journal of Scientific Psychology*, and is a reviewer for nine other peer reviewed journals. Anand has over forty publications and presentations and is a member of the Education and Training Committee of the Human Factors and Ergonomics Society. Anand is also the Principal Investigator of the Abnormal Situation Management Consortium, which is a research consortium focusing on operator effectiveness in the processing industry.