Systems Engineering Advancement Research Initiative

Human-model interactivity:

what can be learned from the experience of pilots with the glass cockpit?

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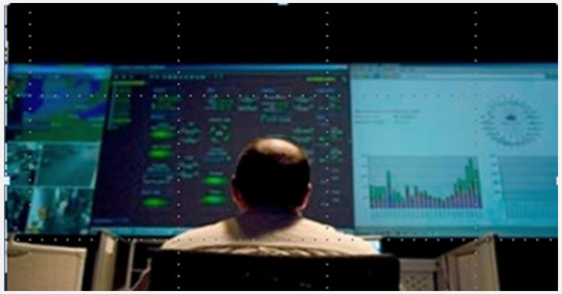
Overview

- Interactive Model-Centric SE
- Human-model interaction
- Glass cockpit analogy
- Accident case examples
- Cognitive and perceptual challenges
- Heuristics for mitigation
- Discussion
- Future research

Interactive Model-Centric Systems Engineering (IMCSE)

The IMCSE research program arises from the opportunity to investigate the various aspects of humans interacting with models and model-generated data. Future environments and practices need to leverage advancements in data science, visual analytics, and complex systems.

IMCSE aims to develop transformative results through enabling **intense human-model interaction**, to rapidly conceive of systems and interact with models in order to make rapid trades to decide on what is most effective given present knowledge and future uncertainties, as well as what is practical given resources and constraints



Rhodes, Donna H. and Ross, Adam M., *Interactive Model-Centric Systems Engineering (IMCSE) Phase Three Technical Report SERC-2016-TR-102,*, March 1, 2016.

Cognitive and Perceptual Aspects of Human-Model Interaction

2015 IMCSE Pathfinder Workshop Findings: confirmed progress has been made for model-based systems engineering, yet little attention has been given to *human-model interaction*

Shift from traditional, document-centric SE to technology enabled, IMCSE

Analogy Case

Transition to Glass Cockpit: investigate challenges and lessons learned from ***human interaction*** with highly automated cockpit systems and displays that may inform IMCSE

Purpose: spark thought and discussion about the role of human-interaction within IMCSE

Analogy Case Findings

Transition to Glass Cockpit

Model: “abstraction of reality” used to augment humans ability to understand the world and predict outcomes

We postulate that relevant similarities exist to the experience of system designers and decision makers transitioning to immersive model-centric environments, with increased abstraction of systems information.

Glass Cockpit Impact: increased use of advanced technology and autonomy that not only changes the role of pilots, but also fundamentally changed piloting by adding an additional role, **manager of systems**

Cognitive Challenges

- Coherence: accurate “picture of reality”
- Disruptions of Coherence

Mitigations

Perceptual Challenges

- Human-Computer Interface
- Preference-Performance Dissociation

Rhodes, Donna H. and Ross, Adam M., *Interactive Model-Centric Systems Engineering (IMCSE) Phase Two Technical Report SERC-2015-TR-048-2*, February 28, 2015

Glass Cockpits

- Glass cockpit technology introduced in the 1970s
  - Originally referred to cathode ray tube displays
  - Now describes digital flight displays and automation systems in general
- Increased commercial use in the 1980s
  - Increased pilot capability, efficiency, reduced crew size
  - New technology, new pathways to failure

Accident Case Examples

- Nagoya, Japan – April 26, 1994
  - Airbus A300, landing approach, 1070 ft above ground level
  - Erroneous Initiation of Go-Around Mode
  - Pilot intervention, uncontrolled autonomous climb, stall, tail first crash-landing, 264 of 271 fatally injured
- Strasbourg, France – January 20, 1992
  - Airbus A320, change from circling to straight in landing approach
  - Inputted “33” to command descent angle of 3.3 degrees
  - Actually commanded descent rate at 3,300 ft/min, 85 of 96 fatally injured
- Cali, Colombia – December 20, 1995
  - Boeing 757, unexpected straight in landing approach
  - Flight computer suggested “ROMEO” rather than “ROZO”
  - Mistake realized, but new course resulted in mountain-side collision, 159 of 163 fatally injured

Coherence

- Pilot as Manager of Systems
  - Shift from "stick and rudder" skills, to programming and monitoring of the system's automation
- Key responsibility to maintain coherence
- Potential causes of coherence breakdown
  - Cognitive Challenges
    - Automation Bias
    - Mode Error
  - Perceptual Challenges

Coherence: maintaining logical consistency in diagnoses, judgments, or decisions

Mosier, Kathleen L, Linda J Skitka, Melisa Dunbar, and Lori McDonnell. "Aircrews and Automation Bias: The Advantages of Teamwork?" *The International Journal of Aviation Psychology* 11, no. 1 (2001): 1-14.

Cognition: Automation Bias

- Automation Bias: "The use of automation as a heuristic replacement for vigilant information seeking and processing," can lead to:
  - Commission and Omission errors

Mosier, Kathleen L, and Linda J Skitka. "Automation Use and Automation Bias." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* Santa Monica: Human Factors and Ergonomics Society, 1999. 344-348.

Cognition: Automation Bias

- Automation Bias: "The use of automation as a heuristic replacement for vigilant information seeking and processing," can lead to:
  - Commission and Omission errors

- Key Influences on Automation Bias
  - Path of least cognitive effort
  - Automation decision making perceived as superior
  - Diffusion of responsibility to automation

Cali Commission Error: blindly accepting ROMEO as the waypoint

Strasbourg Omission Error: assumption that descent automation was performing as intended

Strasbourg

Mosier, Kathleen L, and Linda J Skitka. "Automation Use and Automation Bias." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* Santa Monica: Human Factors and Ergonomics Society, 1999. 344-348.

Cognition: Mode Error

- Modes: structure complexity and tailor automation to specific situations and user preferences
  - Ex: autopilot & manual modes
- Mode Error: losing track of mode the system is in, resulting in misinterpretation of the situation and subsequent erroneous actions
  - Creates "automation surprises"
- NASA study: 55% of pilots encountered "automation surprises" after a year of flying with glass cockpits

Nagoya

Nagoya and Strasbourg: failure to understand and comprehend aircraft modes

Perception:
Presentation of Information

- Wright and O’Hare: glass vs analog, which performs better?
  - Analog instruments resulted in better performance in two separate studies
- Dial instruments relate information in relation to an entire range of numbers
  - Interpretation of information at a glance

Design Consideration: importance of deciding not only what information should be presented, but also how it is presented

Perception:
Preference-Performance Dissociation

- Wright and O'Hare study
  - Users greatly preferred glass cockpit displays to traditional
    - Glass cockpit: "most awareness-enhancing, the least mentally demanding, and the easiest to interpret" display with the "fewest disliked features"
  - Glass cockpit performed demonstratively worse
- Preference-Performance Dissociation phenomenon
  - Users' preferences do not line up with performance

Design Consideration: design for how the user actually performs, not only for what the user wants

Wright, Stephen, and David O'Hare. "Can a glass cockpit display help (or hinder) performance of novices in simulated flight training?" *Applied Ergonomics* 47 (2015): 292-299.

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Mitigating Heuristics
Relevant to IMCSE

- Accountability
  - Mitigation for Automation Bias
- Transparent Systems
  - Operators appropriately aware of state and future behavior
  - Addresses mode error resulting from lack of awareness
- Human-Centered Design
  - Humans bearing ultimate responsibility
  - Integration of humans rather than adapting of humans
  - Highly capable vs highly effective systems

Discussion

Efficiency
Efficacy
Enhancement

Cognitive Challenges
- Coherence: accurate “picture of reality”
- Disruptions of Coherence

Mitigations

Perceptual Challenges
- Human-Computer Interface
- Preference-Performance Dissociation

Future Directions

- Examine near "misses" where automation contributed to a mistake, but operators recognized the mistake in time and prevented an accident
- Explore further analogy cases to uncover corroborating/additional challenges and mitigations
- Learn from Human-Systems Integration (HSI) and Human-Computer Interaction (HCI)
- Develop heuristics of relevance for IMCSE theory and practice

Gather real-world experiences/stories of human-interaction

Questions?

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Complacency

- Complacency: "Unjustified assumption of satisfactory system state," "characterized by a low index of suspicion"
  - Primary concern of pilots in regards to safety and automation in NASA 1970s study
- Automation complacency: "poorer detection of system malfunctions under automation control compared with manual control"
  - Active diversion of attention from automation to other manual tasks
  - Manifests itself under periods of high, multi-task work load
- Closely related to Automation Bias/Errors of Omission

Nagoya: failure to disengage Go-Around mode and assuming satisfactory state

Strasbourg and Cali: failure to verify aircraft's actual state

Cali