The 8th COE Postdoctoral and Doctoral Researchers Technical Presentation

Human Performance Modeling for User Interface Evaluation in Plant Operations

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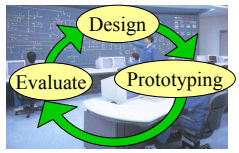
User Interface Evaluation for Plant Operations

- User interfaces (UIs) in human supervisory control system are safety-critical.
- Human errors originate from a bad UI system.
- A good UI system can improve human operator's performance.

Objective→ Investigate human performances for various UI designs to find obstacles and pitfalls in a UI system and improve the UIs.



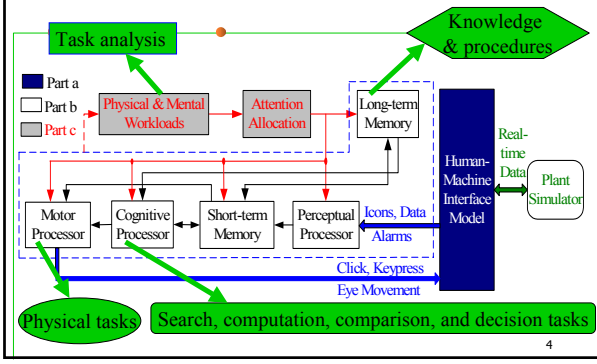
Estimation of Human Performance

- Accomplishment of a task by human operator.
  - Perceptual performance
  - Cognitive performance
  - Memory performance
  - Motion performance

  Static evaluation

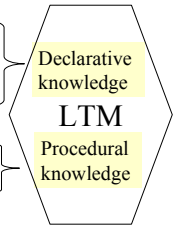
  Dynamic evaluation
- Estimation approaches.
  - Experimental approach
  - Subjective approach
  - Model-based approach ✓

Research Framework



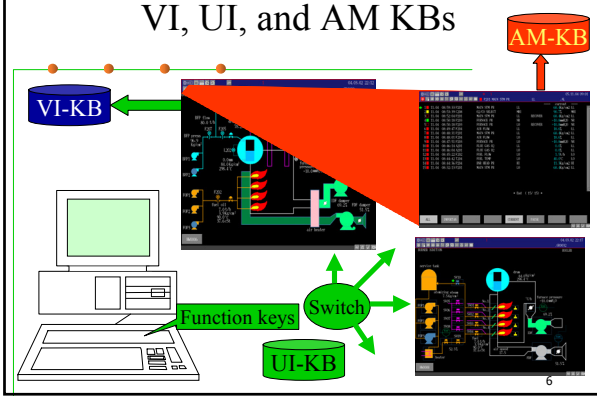
Knowledge Bases and Procedures

- Knowledge bases:
  - Variable information (VI-KB)
  - User interface information (UI-KB)
  - Alarm management (AM-KB)
  - Failure-symptom (FS-KB)
- Procedures:
  - Normal state monitoring (NSM)
  - Abnormal state supervising (ASS)

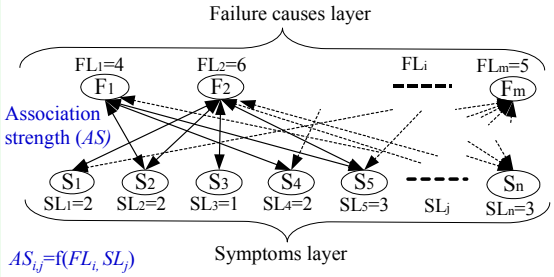


Currently, we focus on the UI evaluation during the course of fault detection and identification (FDI).

VI, UI, and AM KBs



Link Network in FS-KB



$AS_{i,j}=f(FL_i, SL_j)$

FL_i: number of symptoms for ith failure

SL_j: number of failure causes related to jth symptom

Abnormal State Supervising Procedure

- Obtain a symptom S_m from an alarm message according to the AM-KB.
- Find all suspect failure causes that are linked to S_m by the descending order of AS.
- Reject or confirm the suspect failure causes sequentially by their corresponding symptom(s).
- Identify a failure cause whose total AS value exceeds a specified threshold.

Analysis of Fault Detection and Identification (FDI) Task

- Decompose physical and mental tasks for FDI.
  - Perception subtask
  - Cognition subtask
  - STM subtask
  - LTM subtask
  - Physical subtask

Mental subtask

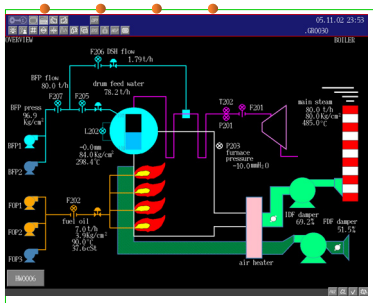
Workload Estimation

- Workloads are estimated according to requirements of mental and physical subtasks.
- Based on the workload estimation of each subtask, operator model totalizes workloads for several subtasks with one goal (a step in FDI track).
- All subtasks are recorded and an FDI track is produced after an evaluation scenario.
- Changes in workloads during the course of FDI are obtained.

Evaluation Procedure

- Build the HMI model and UI-KB for the UI system.
- Build VI-KB, AM-KB,and FS-KB based on process and alarm system.
- Build ASS procedure according to the experiences of plant operations.
- Through FDI simulation, we can obtain the track of human behavior with changes in physical and mental workloads, and time until identifying a failure cause.
- Based on the FDI performance, evaluate the UIs including the alarm system and improve them if necessary.
- All above steps are repeated until an acceptable result is obtained.

Case Study



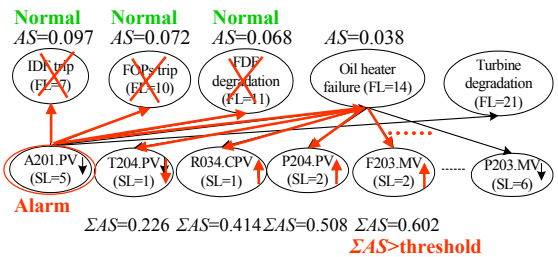
Evaluation of:
- An overview panel
- Alarm system

Investigate FDI behavior by the operator model

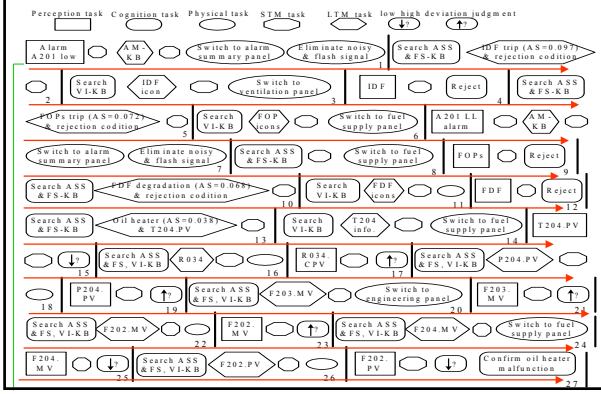
Alarm Messages for Original UI System

No.	Time	Elapsed time (sec.)	Item	Item description	Alarm	Alarm description
1	12:31:44	317	F204	Air flow	LL	PV low-low alarm
2	12:29:58	211	F204	Air flow	LO	PV low alarm
3	12:29:48	201	P203	Furnace pressure	LO	PV low alarm
4	12:28:11	104	A201	Flue O_2 concentration	LL	PV low-low alarm
5	12:28:01	94	A201	Flue O_2 concentration	LO	PV low alarm

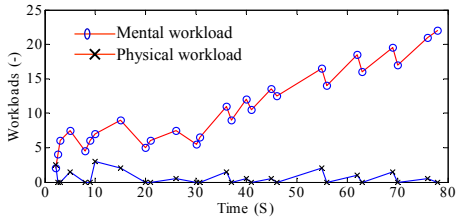
FS links for FDI from A201 Alarm



FDI Track for the Original UI System



Workload Graph for the Original UI System

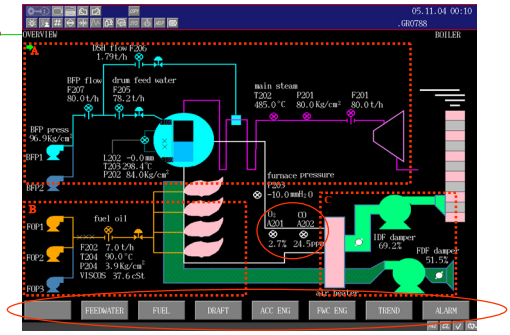


Problems and Solutions

- Important process variables A201 and A202 are not shown on the original overview panel.
- The first alarm does not have close relation with the actual failure cause.
- Switching between panels increases memory workload.

- Add A201.PV and A202.PV on overview panel.
- Supply shortcut buttons and area on overview panel.
- Modify alarm limitations for two process variables—burner-head pressure P204.PV and fuel temperature T204.PV.

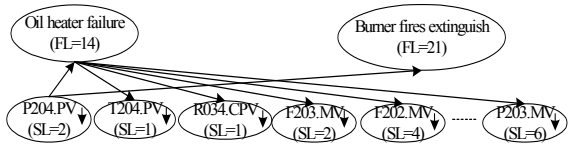
Modified Overview Panel



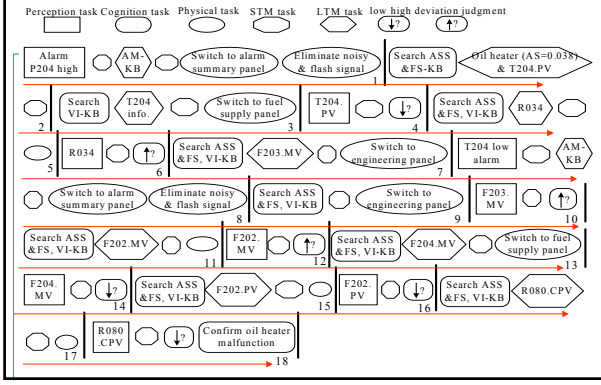
Alarm Messages

No.	Time	Elapsed time (sec.)	Item	Item description	Alarm	Alarm description
1	8:47:51	202	P203	Furnace pressure	LO	PV low alarm
2	8:46:14	105	A201	Flue O_2 concentration	LL	PV low-low alarm
3	8:46:04	95	A201	Flue O_2 concentration	LO	PV low alarm
5	8:44:42	13	T204	Fuel temperature	LO	PV low alarm
6	8:44:36	7	P204	Burner head pressure	HI	PV high alarm

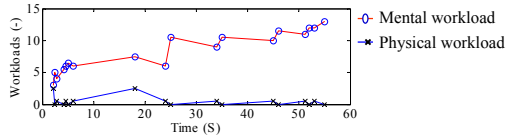
FS Links for FDI from P204 Alarm



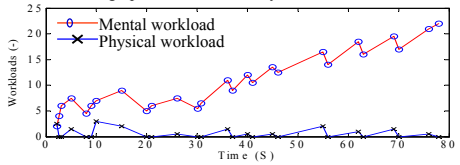
FDI Track for the Modified UI System



Comparison of Workload Graphs



Workload graph for modified UI system



Workload graph for original UI system

Conclusions

- A human-machine system framework is proposed to evaluate human performances in an emergency.
- In a preliminary case study, the FDI track is shorten, and workloads decrease after the evaluation and improvement based on the operator model.
- The case study shows its usefulness to support the design and evaluation of user interfaces in plant operations.

Future Work

- Investigate more case studies.
- Improve the workloads estimation.
- Implement attention resource allocation.
- Improve the fidelity of human model by experiments.