The 1st COE Postdoctoral and Doctoral Researchers Technical Presentation

Modeling human behavior of fault detection and identification in plant operations

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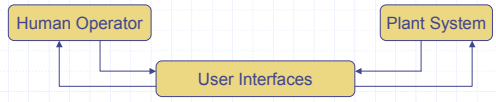
Background

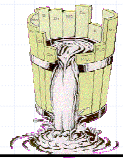
- Human supervisory control system is a safety-critical interactive system.
  - A human operator commonly need cope with 200 alarms in a day[1].
- User interface in plant operations may bottleneck human performance, especially in an emergency.
  - Unfortunately, the designers of these interfaces are not usually the end users.



[1]Society of Chemical Engineers, Japan: Questionnaire report about plant operations and technology transfer (2005).

Model-based Dynamic Evaluation

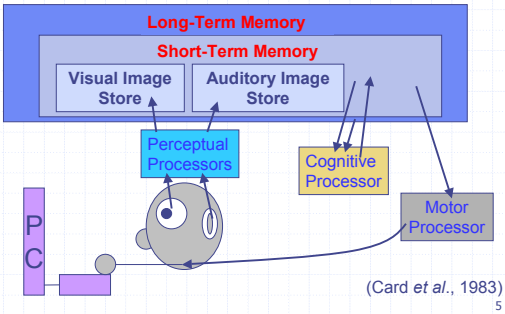
- Model-based evaluation method is flexible to investigate various user interfaces.
- Analyzing operator's behaviors of fault detection and identification in an emergency is helpful to find latent weak points or good solutions.
- Model-based dynamic evaluation means applying an operator model to an abnormal industrial process (off-line data or simulator).



Objectives

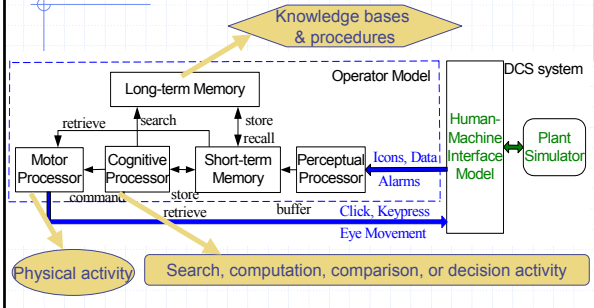
- A human model for dynamic evaluation of operational panels and alarm system.
- A dynamic evaluation method to assess the usability of a user interface system by using the human model.

Basic Model: Model Human Processor



(Card *et al.*, 1983)

Our Operator Model



Knowledge Bases & Procedure

- Knowledge bases:
  - KB-1: Variable information
  - KB-2: Alarm management
  - KB-3: Failure-symptom
- Procedure:
  - Abnormal state supervising

KB-1 (VI-KB) and KB-2 (AM-KB)

Variable information knowledge base

User panel No.: overview2

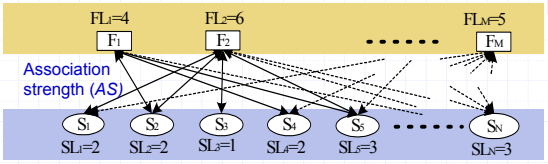
Process variable	Shape	Size (pixel²)	Color	Coordinates (pixel) X	Y	Normal value	U
F201.PV	data	1984	White	1107	346	80	
T201.MV	data	2016	White	1090	396	485	
P201.MV	data	2801	White	1120	369	80	
BFP2.MV	icon	5278	SteelBlue	63	559	0	
STEAM TEMP	icon	2520	Magenta	778	331	485	
STEAM PRESS	icon	2153	Magenta	777	390	80	
L202.PV	data	6081	White	315	453	0	
FOP2.MV	icon	5123	Orange	63	780	1	
FOP3.MV	icon	5123	SteelBlue	63	876	0	

Alarm management knowledge base

Tag name	Setup value HH	PH	PL	LL	VL	DL	MH	ML	SH	SL	MSI
P201	90	85	75	70	100	100	100	0	100	0	10(
P202	100	100	0	0	100	___	___	___	100	0	___
P203	100	50	-50	-100	200	200	100	0	-100	100	10(
P204	15	15	2.2	2	15	15	100	0	15	0	10(
P205	15	15	0	0	15	___	___	___	15	0	___
P206	100	100	0	0	100	___	___	___	100	0	___
P207	10	10	0	0	10	10	100	0	10	0	10(
P208	10	10	0	0	10	10	100	0	10	0	10(

KB-3 (FS-KB)

Failure causes layer

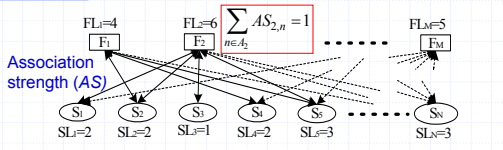


Symptoms layer

- Mapping among failure cases and symptoms

FL_m: number of symptoms for mth failure
SL_n: number of failure causes related to nth symptom

Association Strength



$$AS_{K,H} = \frac{w_{K,H}}{SL_H \sum_{n\in A_K} \frac{w_{K,n}}{SL_n}}$$

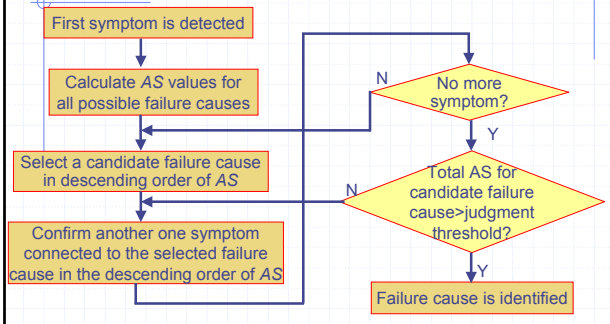
Contribution of Hth symptom to Kth failure cause

A_K : index set of all symptoms connected to F_K
$w_{K,n}$: weight of F_K-S_n link

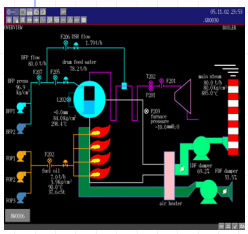
How to Build FS-KB

- Cause-effect analysis for possible malfunctions.
- Standard diagnostic procedures in manuals.
- Experiences
  - Statistical reports
  - Questionnaire to expert operators

Abnormal State Supervising Procedure



Case Study for Boiler Plant

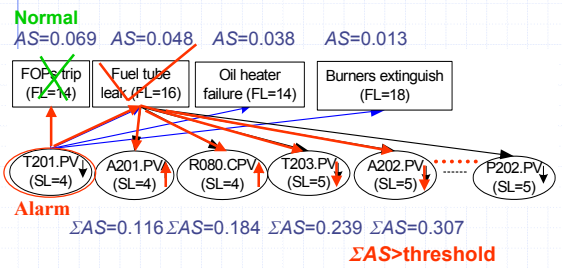


Overview panel

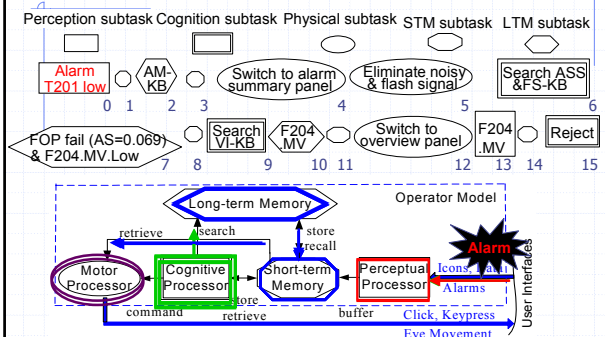
Malfunction list
M1: FOP failure
M2: Burners miss fire
M3: BFP trip
M4: water tube leakage
M5: O2 sensor error
M6: FDF degredation
M7: IDF trip
M8 Turbine trip
M9: oil heater failure
M10: P204 sensor error
M11:Fuel tube leakage

Measurement list	
Tag name	Description
P201	Main steam pressure
P202	Drum press indicator
P203	Furnace pressure
P204	Burner head pressure
P205	fuel pump outlet pressure
P206	BFP outlet pressure
P210	atomizing steam pressure
F201	Main steam flow
F202	Fuel flow
F203	Fuel auto selector
F204	Aire flow
F205	Drum feedwater flow
F206	desuperheater spray flow

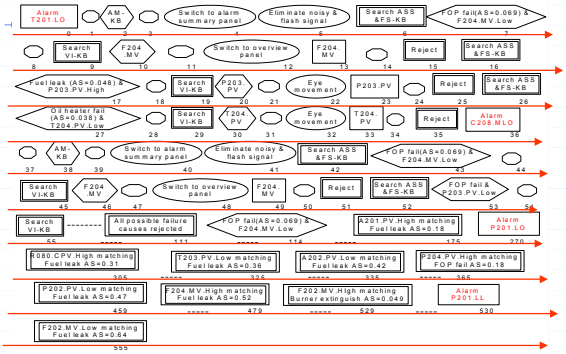
FDI Process



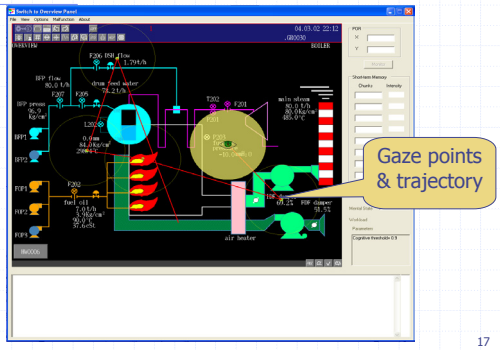
Generation of FDI Track



Generated FDI Track



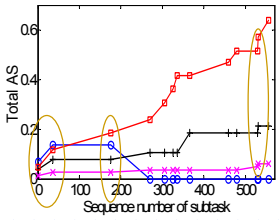
Simulation of FDI Process



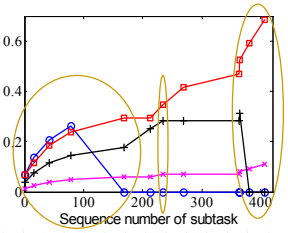
Evaluation Results of Two Alarm Systems

	Alarm system 1	Alarm system 2
Number of Alarm	4	9
Number of subtask	556	422
Shift distance of gaze point	760cm	575cm

Comparison of Two Cases



Alarm system 1



Alarm system 2

Criteria of Model-based Evaluation

- Number of subtasks
- Total shift distance of eye movement
- Changes in total AS values

Conclusions

- An operator model was proposed for dynamic evaluation of graphic panels and alarm system in an emergency.
- Alarm settings of a boiler plant simulator were evaluated by modeling the human behaviors of fault detection and identification.