Support the Design of User Interfaces for Plant Operations

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List of Contents

Different User Interfaces

- UI design for plant operations is important for plant safety.

Plant operations

Objectives

- Evaluate user panels based on a human model.
- Reveal weak points on the panels.
- Investigate effective improvement methods.
- Static evaluations
  - Plant system is under normal state.
  - A human perception model.
  - Evaluate each graphic item and layout of user panels.

Human Perception Model -- Visual Field

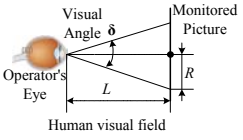
- Visual field

Human visual field is defined as a circle around a fixed point

$$R = L \times \tan(\delta(A_p))$$

$$\delta(A_p) = A_p \times \frac{\delta_0}{2}$$

Ap: perceptual attention level
L : length
R : visual field radius
$\boldsymbol{\delta}$: visual angle
$\boldsymbol{\delta_0}$: constant



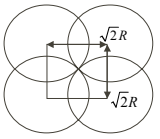
- The default value of L is 75cm.
- Ap is set to high, middle, and low levels (0.8, 0.6, and 0.4) according to former research (Kurooka et al., 2001).
- $\boldsymbol{\delta_0}$ is set to 10° based on EPIC cognitive architecture (Kieras et al., 1997).

Human Perception Model —Eye Movement

- Shift span is defined by the centric distance of two consecutive visual fields in the horizontal or vertical direction.
- Only when it is smaller than $\sqrt{2}R$ can the scanning cover all points on a panel.

$$D = \frac{\sqrt{2}R}{\alpha}$$

D: shift span
α : overlay level



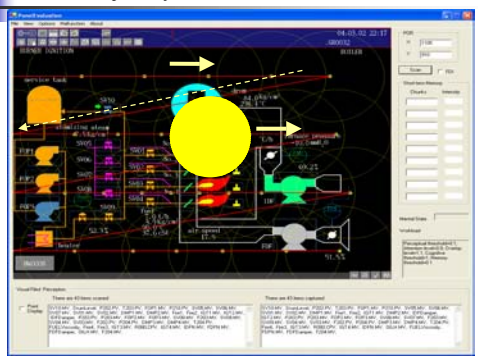
Shift span of saccade

- α_1=1.1
- α_2=(1+k × N) α_1

k: constant
N: number of graphic items in current visual field
α_1: vertical overlay level
α_2: horizontal overlay level

Eye Movement (Cont'd)

- Shift trajectory



Human Perception Model —Visual Performance

- Visual strength of a graphic item within a visual field
  (Weber-Fechner's law)

$$V = f(u, x, y, z, Ap)$$

u: shape of the item
V: visual strength of the element
x: color difference
y: size
z: position

$V < \theta_P$ (Perceptual threshold) → The item is not captured into the short-term memory.

- The maximum capacity of human visual memory is 17 letters (Card, et al., 1983).

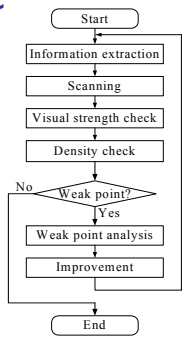
  If the number of graphic items within a visual field is more than 17, some items with less visual strength are lost.

Evaluation Procedure

- **Visual strength check for each item**

  Compare with two judgment thresholds that are defined to detect weak items from important and common items, respectively.

- **Auxiliary checks**
  - average visual strengths and deviations.
  - Density checks
    - Quantity density: maximum number of items within a visual field
    - Area density: effective area ratio (total area of items in a user panel divided by area of the panel); Average area for one item.



User Panels for a Boiler Plant Simulator

Overview | Operation panels | Engineering panels

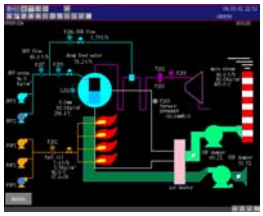
Overview | Burner ignition | Water feed

Draft | Combustion control | Water feed control

Case 1—Evaluation of Overview Panel

- All of the iconic and digital information are extracted to a table that includes importance level, tag name, shape, size, color, position, status, and value of every graphic item.

User panel



Process variables table

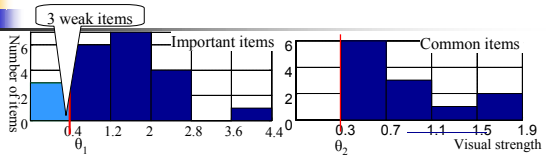
Important and Common Items

- Important items include
  - Icons of principal equipment.
  - Characters or icons of key process variables.
  - Icons of important valves.
- Remaining items are thought of as common items.
- Judgment threshold for important items—θ_1 is bigger than that of common items—θ_2 . The definition of the judgment thresholds is different for 3 types of user panels.

Definition of judgment thresholds in the case studies

panels for	Overview	Operations	Engineering
θ_1	0.4	0.35	0.2
θ_2	0.3	0.25	0.2

Visual Strength and Density Checks

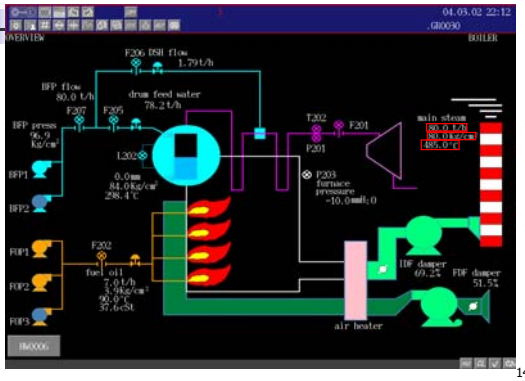


Visual strength histograms of original overview Panel

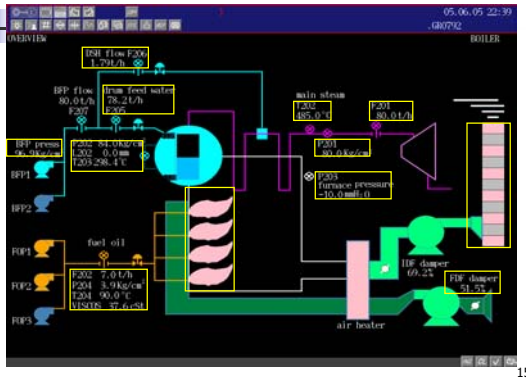
Original overview	Average visual strengths	Average deviations
All items	1.20	0.61
Important items	1.38	0.66
Common items	0.88	0.35

- Maximum number of items within a visual field is 7 at the fixation point (175 436).
- Effective area ratio of items to the whole space is 19.2%.
- Average area for one item is 7622 pixel^2 per item.

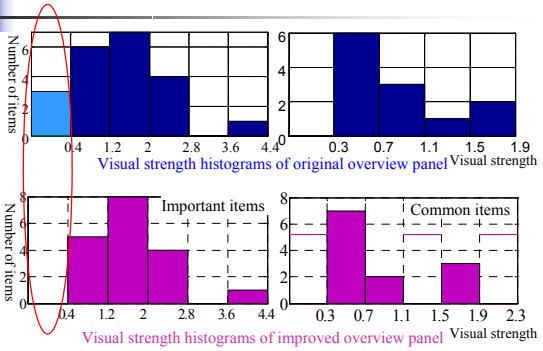
Identification of Causes



Improved Overview Panel



Improvement Effects



Visual strength histograms of original overview panel

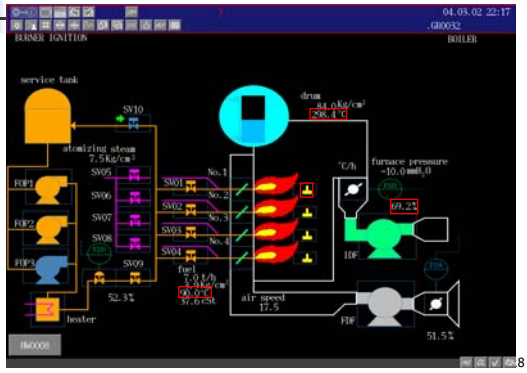
Visual strength histograms of improved overview panel

Improvement Effects (Cont'd)

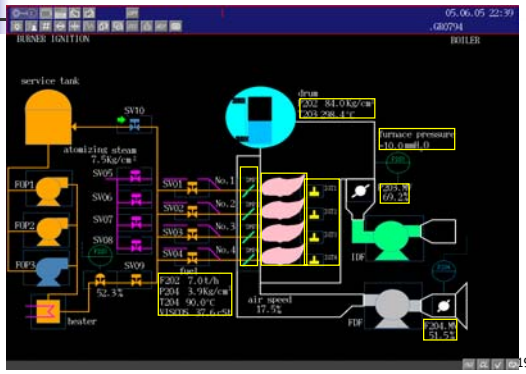
Improved overview	Average visual strengths	Average deviations
All items	1.20→1.31	0.61→0.63
Important items	1.38→1.60	0.66→0.64
Common items	0.88→0.87	0.35→0.41

- Maximum number of items within a visual field is 7 at the fixation point (231, 436)
- Effective area ratio of items to the whole space is 18.7%.
- Average area for one item is 8154 pixel^2 per item (corresponding value of original panel is 7622).

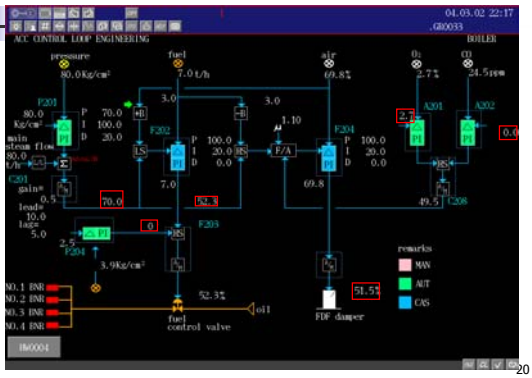
Case 2—Evaluation of Burner Ignition Panel



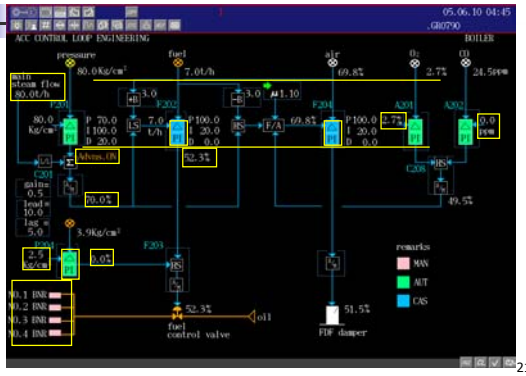
Improved Burner Ignition Panel



Case 3—Evaluation of Combustion Control Panel



Improved Combustion Control Panel



Weak Items on Six Panels

User panels	Purposes	Total number of graphic items (weak items)	Number of Important items (weak items)	Number of common items (weak items)
Overview	Overview	33 (3)	21 (3)	12 (0)
Water feed	Operation on water feed system	26 (1)	11 (1)	15 (0)
Burner ignition	Operation on fuel system	52 (4)	25 (1)	27 (3)
Draft	Operation on draft system	20 (0)	9 (0)	11 (0)
Combustion control	Engineer operations on fuel system	45 (6)	13 (1)	32 (5)
Water feed control	Engineer operations on water feed system	40 (1)	20 (1)	20 (0)

- After modification and reevaluation, all the weak items are improved.

Auxiliary Checks

General density?

Item size?

Panels	Maximum number of items within a visual field & fixation position		Average visual strength for all items	Average deviations for all items	Effective area ratio (%)	Average area per item (pixel²)
	Original panel	improved panel				
Overview	7@(175, 436)	7@(175, 436)	1.20→1.31	0.61→0.63	19.2→18.7	7622→8154
Water feed	5@(208, 199) and (805, 436)	5@(208, 199) and (790, 436)	1.11→1.13	0.55→0.53	19.0→19.3	9565→9749
Burner ignition	14@(436, 673) and (534, 673)	13@(537, 673)	0.95→1.07	0.57→0.45	18.1→20.2	5517→6146
Draft	6@(175, 673) and (190, 436)	6@(175, 673) and (190, 436)	1.24→1.24	0.43→0.43	14.9→15.2	9733→9932
Combustion control	9@(141, 673) and (253, 436)	11@(399, 436)	0.92→0.95	0.56→0.46	19.1→18.3	5565→5331
Water feed control	11 @ (276, [illegible])	9@ (1008, 673) and (388, 436)	1.12→1.16	0.59→0.47	18→17.3	5882→5672

Local density?

Operability?

Smooth?

Improvement Methods

- Add enough information for weak items such as tag name or other descriptive words. (size)
- Adjust the character's font size. (size)
- Introduce an icon for a character item. (size, shape)
- Combine several redundant items. (size)
- Adjust color definition. (color)
- Group a cluster of items with close relations. (position)

Improvement Principles

- Overview and engineering panels should be clear and concise. The modification on these panels should mainly be done by adjusting the layout.
- Items on overview panel should be grouped by equipment configuration in the field.
- Items on engineering panel is required to place according to their roles in control systems.
- Operation panels should have a good consistency and are designed based on a series of defined rules. It is better to improve the operation panels by adjusting size and shape factors.

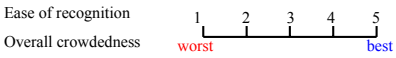
Heuristic Evaluation

- **Heuristics on visual effect**
- Part I: List weak items
  - Small size
  - Obscure color
  - Ambiguous annotation
  - Locally crowded
  - Alignment
  - Consistency on color, size, symbol
- Part II: General evaluation
  - Ease of recognition (5 levels)
  - overall crowdedness (5 levels)

Heuristic Evaluation Result

- For user panel—burner ignition

Expert	panels	Number of weak item	General evaluation	
			Ease of recognition	Overall crowdedness
A	Original panel	14	1	3
	Modified panel	8	3	3
B	Original panel	14	2	3
	Modified panel	6	3	3



Summary

- A perception model is proposed and used for static evaluations when the plant system is normal and stable.
- 6 user panels for a boiler plant simulator were evaluated from the viewpoint of human perception.
- Based on the evaluation results, we improved these panels and validated the usefulness of the presented approach by heuristic evaluations.