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How Many Parameters May Be Displayed on a Large Scale Display Panel?

Hyun-chul Lee, Bong-shick Sim, In-suk Oh, and Kyoung-ho Cha
Korea Atomic Energy Research Institute

ABSTRACT

Large scale display panel(LSDP) is a main component in the next generation main control rooms. LSDP is located at the front of VDU-based operator's workstation and plays an important role in providing operators with overall information of plant status through mimic diagram, text/digit, graph, and so on. A critical matter determined at the first stage of LSDP design is how much information is displayed, because the information density of LSDP affects operator's performance. Many human factors guidelines recommend low information density of displays to avoid degrade of operator's performance, but doesn't provide a useful limit of information density. In this paper, we considered information density as the number of plant parameters and investigated the proper number of plant parameters through a human factors experiment. The experiment with 4 subjects was carried out and response time, error, and heart rate variation as criterion measures were recorded and analyzed. As the results, it is identified that the proper number of parameters in a LSDP is about thirty.

INTRODUCTION

The next generation main control rooms are proposed by many companies/countries. The main features of them are VDT-based operator workstations, computerized operating procedure and alarm system, operator aiding system, and a large scale display panel(LSDP). Most of next generation main control rooms adopt the LSDP. EPRI's URD chapter 10 provides the requirements of LSDP as follows[1].

- large, upright display
- spatially dedicated
- continuously viewable
- integrated mimic presentation of plant status
- useful during normal. abnormal, emergency situation
- providing key parameters and status indications independent of other displays
- no additional operator's actions and burdening the normal displays
- available to all operators

The amount of information contained in LSDP is very important from the viewpoint of human factors. The information density is defined as target information over background information, represents the amount of information in concerned system. Gilmore et. al. said that the more information density the more human error rate and degradation of human performance[2]. Owing to color or shape coding, however, the calculation of information density is not simple. Thus another definition of information density for this study which is practical and equivalent to the original definition is necessary. The number of plant parameters including the number of parameters for status indication are chosen. If the number of plant parameters is increased or decreased, information density is increased or decreased. In addition the number of plant parameters can be easily understood by designers and controlled by experimenter.

PLANT PARAMETERS SET

EPRI's URD provides some key parameters and plant components for status indication, but they are only minimum parameters to be appeared on LSDP. In order to investigate the proper number of plant parameters, the set of plant parameters should be defined. The plant parameters set can be defined by the role of LSDP. As LSDP is a display for monitoring plant status and provides overall information, plant parameters can be restricted to variables in type B and D category of Regulatory Guide 1.97 and parameters for SPDS(safety parameter display system). Type B and D variables of Regulatory Guide 1.97 provide information to indicate plant safety and SPDS has plant parameters for rapid and reliable assessment of plant status[3,4]. The set of plant parameters is identified through the review of Regulatory Guide 1.97 type B,D variables and IEC 960 appendix A, and the result is same as following.

- REACTIVITY CONTROL
  - Reactor Power
  - Control Rod Position
  - RCS Boron Concentration
- CORE COOLING
  - RCS Hot Leg Water Temperature
  - RCS Cold Leg Water Temperature
  - Core Temperature
  - RCS Pressure
  - Coolant Inventory
  - RCS Flow
- MAINTAINING CONTAINMENT INTEGRITY
  - Containment Isolation Valve Position
  - Containment Pressure
  - Hydrogen Concentration
  - Containment Spray Pump Status
  - Containment Spray Flow
  - Heat Removal by the Containment Fan Heat Removal System
  - Containment Atmosphere Temperature
  - Containment Sump Water Temperature
- RESIDUAL HEAT REMOVAL SYSTEM
  - RHR System Flow
  - RHR Heat Exchanger Outlet Temperature
- SAFETY INJECTION SYSTEM
  - Accumulator Tank Level and Pressure
  - Accumulator Isolation Valve Position
  - Boric Acid Charging Flow
  - RWST Level
  - SI Pump Status
  - SI Valve on/off Status
- PRIMARY COOLANT SYSTEM
  - RCP Status
  - Primary System Relief Valve Position
  - Pressurizer Level
  - Pressurizer Heater Status
  - Quench Tank Level (PRT Level)
  - Quench Tank Temperature (PRT Temperature)
  - Quench Tank Pressure (PRT Pressure)
- SECONDARY SYSTEM
  - Steam Generator Level
  - Steam Generator Pressure
  - Main Steam Flow
  - Main Feedwater Flow
  - MFWP Status
  - AFWP Status
  - Safety/Relief Valve Position
  - Auxiliary Feedwater Flow
  - Condensate Storage Tank Level
- CHEMICAL & VOLUME CONTROL SYSTEM
  - Makeup Flow-in
  - Letdown Flow-out
  - Volume Control Tank Level
- COOLING WATER SYSTEM
  - Component Cooling Water Temperature to ESF
  - Component Cooling Water Flow to ESF
- POWER SUPPLIES
  - Diesel Generator Status
  - Generator Main Breaker Status
  - Fuel Storage Level for the emergency diesel generators

The total number of plant parameters considered in this study is 49 and plant parameters of radwaste/ventilation system and several parameters are not considered.
As the amount of information in LSDP should be determined from the viewpoint of human factors, a human factors experiment is carried out according to APTEA experimental paradigm[5].

A HUMAN FACTORS EXPERIMENT

A balanced incomplete block(BIB) design is used as an experiment design. BIB design is a kind of block design and has a merit of reducing time and cost required for a experiment[6]. BIB design for this experiment is presented at Fig 1. 4 subjects participate in this experiment, 4 level of information density(the number of plant parameters) is investigated, and the total number of experiment run is 12. In this experiment, a subject is considered as one block so that personal differential doesn't affect the result of experiment.

		Level of information density(the number of plant parameters)			
		20	30	40	49
Block (subject)	1	-*	(3)**	(1)	(2)
	2	(2)	(1)	(3)	-
	3	(3)	-	(2)	(1)
	4	(1)	(3)	-	(2)

* : an experiment run is not performed,

** : an experiment run is performed under condition determined by horizontal and vertical value, and the number represents the order of experiment process. That is, first subject carries out the subject's tasks firstly with a LSDP containing 40 plant parameters, and lastly with a LSDP containing 30 parameters.

Fig 1. A balanced incomplete block design for a experiment

In order to determine the proper number of plant parameters in LSDP, response time, error rate, and heart rate variation is used as criterion measures. Response time and error rate are utilized to evaluate how fast and how much accurately operator can get information according to the number of plant parameters in LSDP. Heart rate variation is a useful criterion measure for operator's mental workload, and represent how much mental workload an operator undergo. In general, if mental workload experienced by an operator is increased heart rate variation is decreased. In this experiment, response time is the difference between the time which system's query is displayed and the time which operator's action is completed. System's query is a question of information(parameter's value) on LSDP, and operator's action is input work of the information. Error rate is defined as the number of wrong input of information over the number of input work. Heart rate variation is calculated by the standard deviation of BPM(heart Beat Per Minute), and BPM can be acquired from ECG(electrocardiogram) physiological signals. In addition, as operator won't always monitor LSDP and for the purpose of enhancing detectability of criterion measures, a metal arithmetic task is used as a secondary task.
Equipment's setting for the experiment is depicted at Fig 2. Response time of mental arithmetic and input of information- and error rate of mental arithmetic task are automatically recorded at a subject's workstation(HP-755). Error rate of input of information in LSDP is calculated by manual comparison input value on logging data saved in a IBM compatible personal computer(PC-A). ECG is acquired by telemetry system and saved in another IBM compatible personal computer(PC-B). The standard deviation of BPM is got from Acqknowledge software installed in a personal computer(PC-B). The distance from the LSDP to subject's screen is 420cm, the character size on the LSDP is 2x2cm, and the LSDP size is about 150x120cm.

SUBJECT'S TASK

In this experiment, subjects(operators participated in this experiment) have to perform two tasks, one is the mental arithmetic(MA) task and the other is the input of information(IP) task. MA task should be carried out by subjects whenever a display for mental arithmetic such as Fig 3. is appeared on the subject's screen. If two 3-digit numbers is not appeared and a question of plant parameters value is displayed on the screen(refer to Fig 4.), subjects must perform IP task-a sequence of actions that is reading it, seeking right information(ie. parameter's value) in LSDP, and input the information on the screen. 600 MA tasks and 100 IP tasks is assigned to one experiment run. 4 subjects are trained to participate in this experiment and their readiness for the experiment are tested before real experimentation.

EXPERIMENT DATA AND ANOVA

Average response time of MA task, standard deviation of response time of MA task, error rate of MA task, average response time of IP task, standard deviation of response time of IP task, error rate of IP task, and standard deviation of BPM for each subject are gathered. Fig 5. - Fig 9. represent the major experiment data. ANOVA(analysis of variance) for each experiment data are executed in order to discriminate statistical significance, and its results are tabulated at Fig 10.

CONCLUSION

Only average response time of IP task is statistically significant and confidence interval tests are carried out to identify performance differences between the levels of information density. Subject's performance with a LSDP including 30 parameters is higher than 40 or 49 parameters, and not statistically differs from 20 parameters. Therefore, it is concluded through this experiment that the proper number of plant parameters in a LSDP is about thirty.

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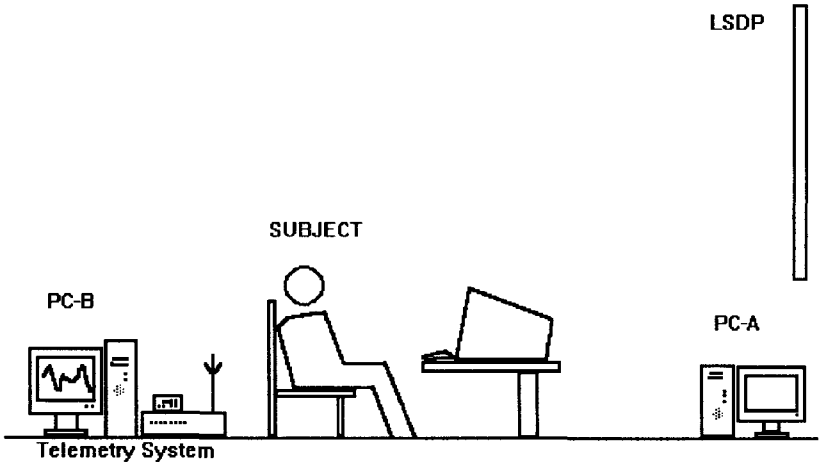

Fig 2. Equipment's Setting

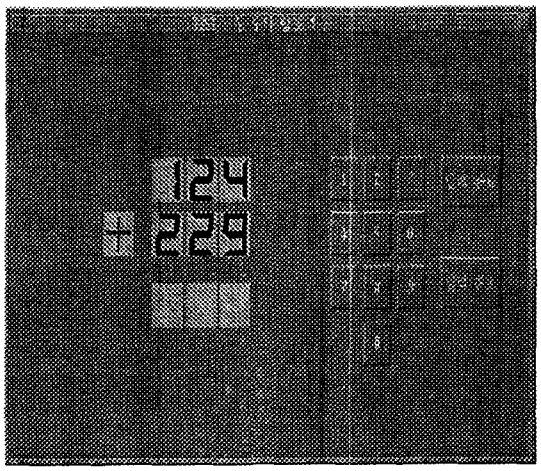

Fig 3. A screen for mental arithmetic task

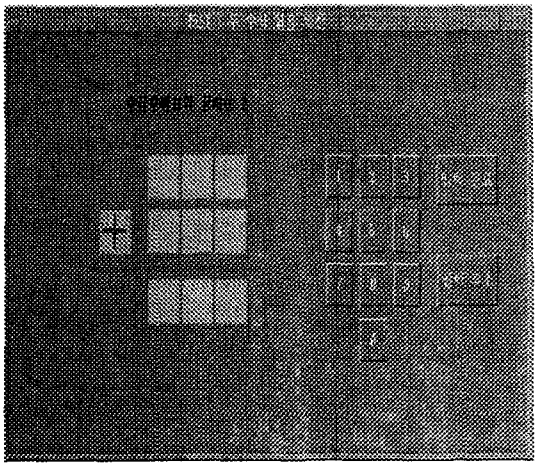

Fig 4. A screen for information input task

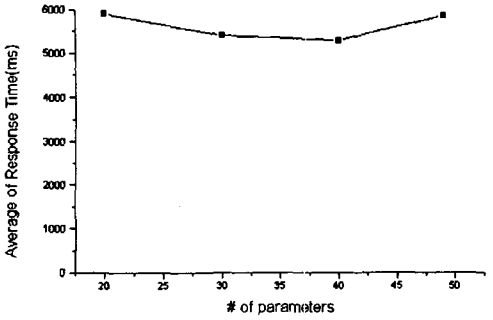

Fig 5. Result graph for MA response time

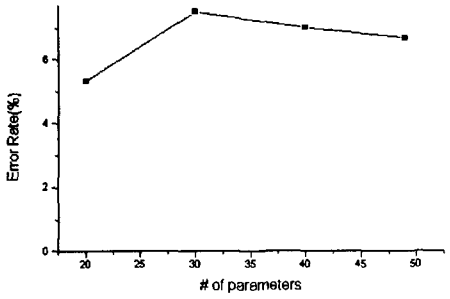

Fig 6. Result graph for MA error rate

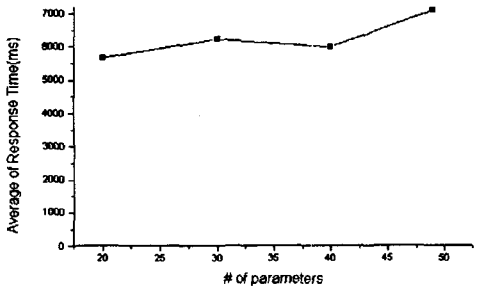

Fig 7. Result graph for IP response time

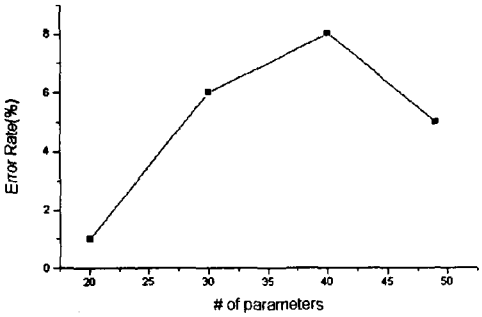

Fig 8. Result graph for IP error rate

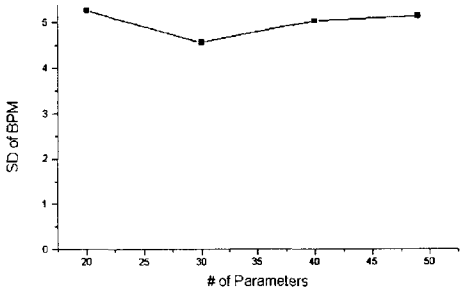

Fig 9. Result graph for stadard deviation of BPM

Treatments	Sum of Square	degree of freedom	Mean Square	F_0	Discrimination
1. Average Response Time of MA task					
Treatment	714259.2251	3	238086.4084	0.9932	Not Significant
Error Term	1198573.895	5	239714.7791		
2. Standard Deviation of Response Time of MA task					
Treatment	172212.6898	3	57404.22994	2.2408	Not Significant
Error Term	128088.1264	5	25617.62529		
3. Error Rate of MA task					
Treatment	1.5733	3	0.5244	0.4314	Not Significant
Error Term	6.0786	5	1.2157		
4. Average Response Time of IP task					
Treatment	936878.5599	3	312292.8533	6.0520	Significant
Error Term	258006.4077	5	51601.28155		
5. Standard Deviation of Response Time of IP task					
Treatment	774968.8055	3	258322.9352	1.5762	Not Significant
Error Term	819435.2228	5	163887.0446		
6. Error Rate of IP task					
Treatment	5.25	3	1.75	0.92	Not Significant
Error Term	9.4167	5	1.8833		
7. Standard Deviation of BPM					
Treatment	1.2212	3	0.4070	1.3068	Not Significant*
Error Term	1.5575	5	0.3115		

* When the Kruskal-Wallis Test, one of the nonparametric analysis, is executed, same results are obtained.

Fig. 10 Results of ANOVA for each criterion measures