APPLICATION OF A HUMAN FACTOR GUIDELINE TO SUPERVISORY CONTROL INTERFACE IMPROVEMENT

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Abstract: In tasks of human supervision in industrial control room they are applied generic disciplines as the software engineering for the design of the computing interface and the human factors for the design of the control room layout. From the point of view of the human computer interaction, to these disciplines it is necessary to add the usability engineering and the cognitive ergonomics since they contribute rules for the user centered design. The main goal of this work is the application of a human factors guideline for supervisory control interface design in order to improve the efficiency of the human machine systems in automation. This communication presents the work developed to improve the Sports Service Area interface of the Universitat Autónoma de Barcelona.

1 INTRODUCTION

In recent years, control systems and the role of control room human operators have changed dramatically. Human operator activity has evolved from manually performing the process, to control system supervision. Today, the human operator requires an in-depth knowledge of the process that he/she is overseeing and the ability to make effective decisions within demanding constraints.

The increased complexity of industrial process control calls for a new methodological approach (for research and design purposes), which reproduces the essential components of current control systems: the environment, the task at hand and human operator activity (Samad and Weyrauch, 2000).

The complexity of industrial process supervision makes it necessary to supplement the Human Factors approach and the Human-Computer Interaction approach with a cross-disciplinary cooperation in order to integrate knowledge and methods from other fields, especially Cognitive Ergonomics, Automation and Artificial Intelligence (Granollers et. al., 2005), (Holstom, 2000) (Petersen, 2000). Our view is that complete control systems engineering must encompass all these approaches.

Ergonomics is concerned with the adaptation of technology to suit human operator need and ability so as to achieve effectiveness, efficiency and user/worker satisfaction and comfort (Cañas, 2004).

Supervisory control is the set of activities and techniques developed over a set of controllers (programmable logic controllers and industrial regulators) which ensures the fulfilling of control goals. One of the main goals is to prevent possible plant malfunctions that can lead to economical lose and/or result in damage (Petersen and May, 2006). For this reason, other fields of knowledge concerned with manufacturing systems performance – such as

maintenance and industrial security – are complementary in the study of supervision systems.

In this paper a methodology for the creation of a human factor guideline for supervisory control interface design is proposed. In section 2 we present a checklist of indicators of the guideline called 'ergonomic guideline for supervisory control interface design' (GEDIS *Guia ergonómica para el diseño de interfaz de supervision* in Spanish version). The Sports Service Area project is described in section 3. The purpose is not to cover with detail the entire project but to give an idea of the different kind of topics that have been covered. In section 4, transition from the GEDIS model to Sports Service Area interface in control room is evaluated. In this section, a set of recommendations about graphical interface improvement are studied. Finally, conclusions and future research lines.

2 GEDIS GUIDELINE

The previous research on human interface design guidelines includes for example the standard ISO 11064 that establishes ergonomic principles for the evaluation of control centers (ISO, 2004), the Human Factors Design Standards HFDS of the Federal Aviation Administration of the United States (Federal Aviation Administration, 1996), the Human Interface Design Review Guidelines NUREG 0700 in nuclear power plants (Nuclear Regulatory Commission, 2002), the I-002 Safety and Automation Systems NORSOK about Norwegian petroleum industry (Norsok, 2006) and the Man Systems Integration Standard NASA-STD-3000 about manned space programs (Nasa, 1995).

An example of cognitive modelling in human computer interaction is the GOMS guideline, about goals, operators, methods and selection rules in usability analysis (Card et. al., 1983). In combination with Keystroke-Level Model KLM an interface can be studied, also task execution time and human efficiency can be studied too.

The GEDIS guide is a method that seeks to cover all the aspects of the interface design (Ponsa and Díaz, 2007). From the initial point of view of strategies for effective human-computer interaction
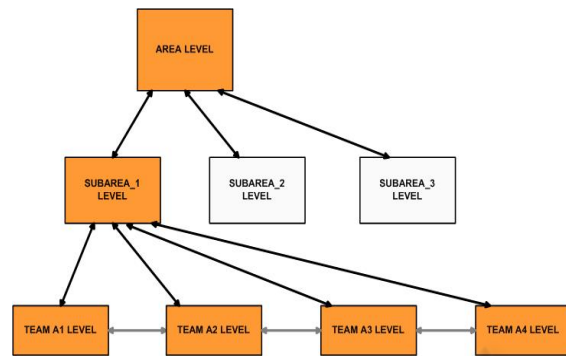

Figure 1: A typical cyclic network menu in supervisory control interface associated to navigation indicator.

applied to supervision tasks in industrial control room (Nimmo, 2004), (Schneiderman, 1997).

The GEDIS guide offers design recommendations in the moment to create the interface. Also, already offers recommendations of improvement of interfaces created. The GEDIS guide is composed of two parts: description of ten indicators and measure of ten indicators. The indicators have been defined from extracted concepts of other generic human factors guidelines, and for aspects of human interface design in human computer interaction.

The method to continue for the use of the GEDIS guide is: analyze the indicator, measure the indicator, obtain the global evaluation index and finally offer recommendations of improvement.

For the correct use of the GEDIS guide it is necessary the collaboration between the control room technical team and the human factor technician, since in some cases to analyze the indicator is necessary the expert's opinion.

2.1 Indicators List

The GEDIS guide consists of ten indicators that seek to cover all the aspects of the interface design in the supervisory control domain. The indicators are: architecture, distribution, navigation, color, text font, status of the devices, process values, graphs and tables, data-entry commands, and finally alarms. For example, the relationship between architecture and navigation indicators is illustrated in Fig. 1. The physical plant can separate in area, subarea, and team. In the same way, the interface presents four navigation levels. Fig. 1 shows a possible layout to locate all the connections between screens. The connection among screens is complex in a supervisory control interface. From the point of view
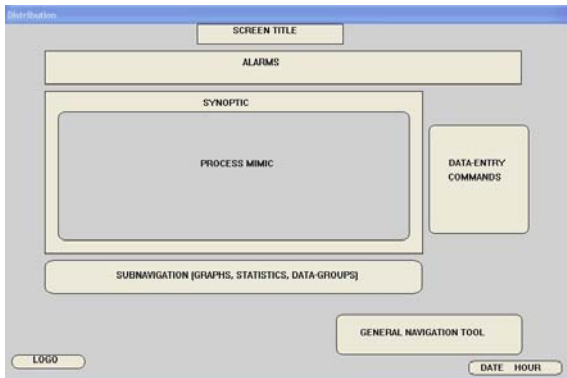
Figure 2: An example of object's layout inside the screen for the distribution indicator.

of human computer interaction, is a typical example of cyclic network menu.

Distribution indicator of Fig. 2 shows a possible layout to locate all the objects inside the screen. The objects homogeneous distribution allows us to maintain the interface coherence when user changes the screen. The secondary objects are located in screen areas that don't require the user's attention (enterprise logo, and date/hour information). The user should recognize the screen title and the general navigation tool to move among screens. The main objects are located in visible screen areas (alarms, data-entry commands, subnavigation tool, and synoptic objects). The user can surveillance the process evolution without acting (human out of the loop), or he can decide to introduce changes in the set point or in the controller's parameters (human in the loop) inside a faceplate window in the data-entry command object. The user should have special attention to the alarm indicators, which should be located in a clear way in the screen so that the user can recognize the situation (situation awareness).

3 SAF PROJECT

This section presents the development of the supervisory control system, with special emphasis on the interface features, for the Sports Service Area (SAF in Catalan version) of the Universitat Autonoma of Barcelona (UAB). This supervisory control system has been developed by a team of Computer Sciences Engineers with common design guidelines. Even some basic principles on ergonomics and interface design were taken into account; the GEDIS analysis will show existing weakness. An alternative presentation of the SAF project can be found in (Vilanova and Gomà, 2006).

Figure 3: Main window of the developed monitoring system with a global view of the Sports Service Area.
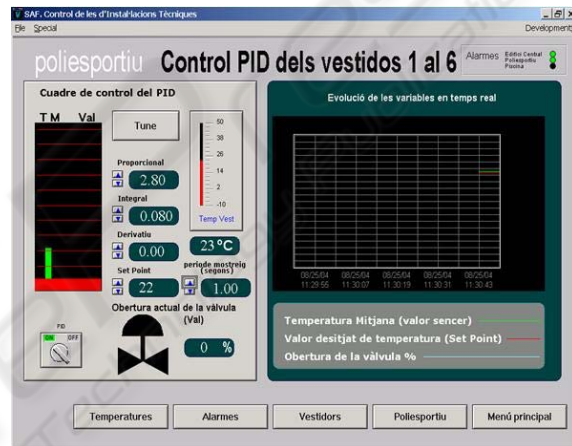

Figure 4: ISA-PID used to close the loops.

First of all, it is worth to know that the UAB is a campus based university with more than 40.000 inhabitants (students, academics, staff, etc.). In fact, this makes the University campus to behave like a city with some sort of facilities offered for their inhabitants. Among them, the Sports Service Area (SAF) is one of the largest and with more complex installations. It encompasses indoor as well as outdoor activities that run for more than 12h each day. Just to give an idea of the different installations that give support to the offered activities. We can find there: covered swimming pool, boulders, outdoor facilities for tennis, football, athletics, etc., indoor installations for fitness, basketball, aerobic, gym, etc. (Antsaklis et. al., 1999), (Astrom, 1999), (Kheir et. al., 1996).

Therefore, large complexes build up from different subsystems. Each one of these subsystems has to assure a quality of service each day. This fact introduces the need for good monitoring tools to help on this task. In addition, there is a hug number

of automation and control problems (automated watering, temperature controls for water and indoor areas, lightning systems, ozone controlled system for water cleaning in covered swimming pools, etc.).

The SAF project has different automation levels: from field instrumentation and data collection, PLC programming and feedback loop configuration, to information integration on a SCADA system. The SAF project use PLC from different manufacturers (SIEMENS, GE-FANUC, Landys, and Mitsubishi). All the data has been integrated through implementing the corresponding supervisory control interface with Wonderware suite called In TOUCH. The basic communications use specific drivers to connect PLC with PC based control; the advanced communications use the standard OPC protocol.

An example: for indoor activities temperature control of both the SAF building and the water for the gym showers has been implemented. This means the students, in control room operator role, had to close some loops by using the ISA-PID present either in the PLC or in the software (see Fig. 4).

One important aspect of a monitoring system is how it deals with alarms. As this feature is a common feature, it should be incorporated in every part of the system according to the same rules. This way, in every SCADA window and alarm indicator has to be included that shows the human operator if an alarm is currently fired and can let you go directly to the main alarm window to process it.

Finally, design implementation and configuration of the In TOUCH based SCADA system has been done starting from zero. This allowed to think of a distributed application where from the different computers located either at the main SAF office or at the technical staff room the overall system can be accessed. In addition a special access, using terminal services, for the technical staff has been enabled so remote operation can also be done from outside the SAF installations.

4 SAF EVALUATION

The connection between SAF designer and GEDIS guideline designer is necessary to define a global evaluation of the SAF interface and can give a set of recommendations about graphical screen improvement (see Fig. 5).
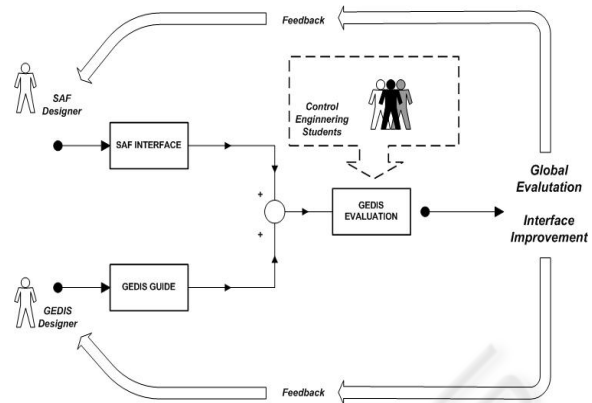

Figure 5: SAF interface evaluation with GEDIS guide method.

4.1 Evaluation

The evaluation expressed in quantitative numeric form or in qualitative format it seeks to promote the user's reflection that stuffs the GEDIS guide by way of questionnaire, so that it picks up the use experience that doesn't end up being verbalized in many occasions.

Each one of the indicators of the Table 1 and Table 2 can substructure in diverse subindicators. For example, the indicator Color can be detailed in: absence of non appropriate combinations (5), number of colors (5), blink absence (no alarm situation) (5), contrast screen versus graphical objects (3), relationship with text (3). For each subindicator it is recommended it is punctuated numerically in a scale from 1 to 5. In this example the number of subindicators of the indicator Color is $J = 5$ (see formula 1). The formula necessary to calculate the numeric value of each indicator is the formula 1.

$$Indicator = \frac{\sum_{j=1}^{J} w_j Subind_j}{\sum_{j=1}^{J} w_j} \quad (1)$$

where, Subind= subindicator and w = weight.

The mean value that one obtains by the formula 1 with these numeric values is 4,2 . If it is rounded, the value is 4, so that to the indicator Color it is assigned the value 4 in this example, considering that each one of the subindicators has the same weight (w1 = w2… =wJ = 1).

Table 1: GEDIS guide indicators (part one).

Indicator name and Subindicator name	Numeric/qualitative range and SAF numeric value	
Architecture	**1,7**	
Map existence	[YES, NO] [5,0]	0
Number of levels le	[le<4, le>4] [5,0]	0
Division: plant, area, subarea, team	[a, m. na] [5,3,0]	5
Distribution	**3**	
Model comparison	[a, m. na] [5,3,0]	3
Flow process	[clear, medium, no clear] [5.3,0]	3
Density	[a, m. na] [5,3,0]	3
Navigation	**3**	
Relationship with architecture	[a, m. na] [5,3,0]	3
Navig. between screens	[a, m. na] [5,3,0]	3
Color	**5**	
Absence of non appropriate combinations	[YES, NO] [5,0]	5
Color number c	[4<c<7, c>7] [5,0]	5
Blink absence (no alarm situation)	[YES, NO] [5,0]	5
Contrast screen versus graphical objects	[a, m. na] [5,3,0]	5
Relationship with text	[a, m. na] [5,3,0]	5
Text font	**3,2**	
Font number f	[f<4, f>4]	5
Absence of small font (smaller 8)	[YES, NO] [5,0]	0
Absence of non appropriate combinations	[YES, NO] [5,0]	5
Abbreviation use	[a, m. na] [5,3,0]	3

where, a= appropriate, m=medium and na = no appropiate.

Each one of the indicators of the Table 1 is measured in a scale from 1 to 5. The human expert operator prepares in this point of concrete information on the indicator, so that it can already value the necessities of improvement. The values of the indicators can group so that the GEDIS guide offers the global evaluation of the interface and it can be compared with others interfaces.

The formula necessary to calculate the GEDIS guide global evalutation index is the formula 2.

$$Global\_evaluation = \frac{\sum_{i=1}^{10} p_i ind_i}{\sum_{i=1}^{10} p_i} \quad (2)$$

where, ind = indicator and p = weight.

Table 2: GEDIS guide indicators (part two).

Indicator name and Subindicator name	Numeric/qualitative range and SAF numeric value	
Status of the devices	**4**	
Uniform icons and symbols	[a, m. na] [5,3,0]	3
Status team representativeness	[YES, NO] [5,0]	5
Process values	**3**	
Visibility	[a, m. na] [5,3,0]	3
Location	[a, m. na] [5,3,0]	3
Graphs and tables	**4**	
Format	[a, m. na] [5,3,0]	3
Visibility	[a, m. na] [5,3,0]	3
Location	[a, m. na] [5,3,0]	5
Grouping	[a, m. na] [5,3,0]	5
Data-entry commands	**3**	
Visibility	[a, m. na] [5,3,0]	3
Usability	[a, m. na] [5,3,0]	3
Feedback	[a, m. na] [5,3,0]	3
Alarms	**3,8**	
Visibility of alarm window	[a, m. na] [5,3,0]	3
Location	[a, m. na] [5,3,0]	3
Situation awareness	[YES, NO] [5,0]	5
Alarms grouping	[a, m. na] [5,3,0]	5
Information to the operator	[a, m. na] [5,3,0]	3

where, a= appropriate, m=medium and na = no appropiate.

In a first approach it has been considered the mean value among indicators expressed in the formula 2. That is to say, to each indicator it is assigned an identical weight (p1 = p2… =p10 = 1) although it will allow it in future studies to value the importance of some indicators above others. The global evaluation is expressed in a scale from 1 to 5. Assisting to the complexity of the systems of industrial supervision and the fact that an ineffective interface design can cause human error, the global evaluation of a supervision interface it should be located in an initial value of 3-4 and with the aid of GEDIS guide it is possible to propose measures of improvement to come closer at the 5.

4.2 Experimental Study

The experimental study is the evaluation of SAF interface with the collaboration of control engineering students from Technical University of Catalonia. From Vilanova i la Geltrú city, twenty five students monitoring SAF interface around three weeks. The students define a numeric value for each indicator and propose interface improvement.
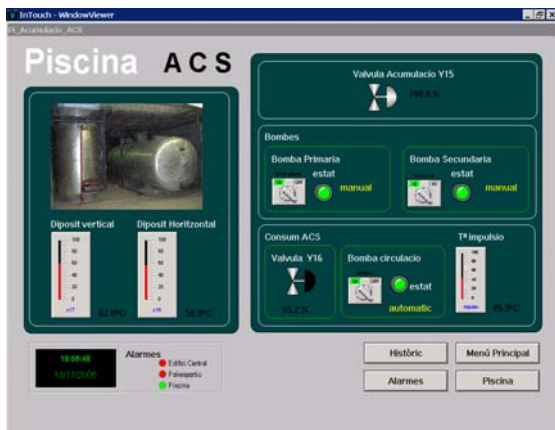
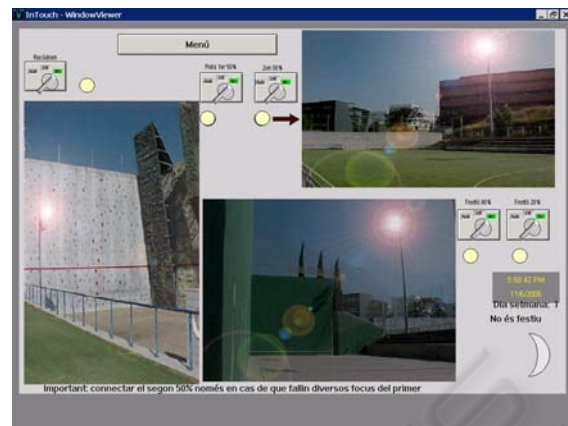Figure 6: Original Piscina ACS screen.

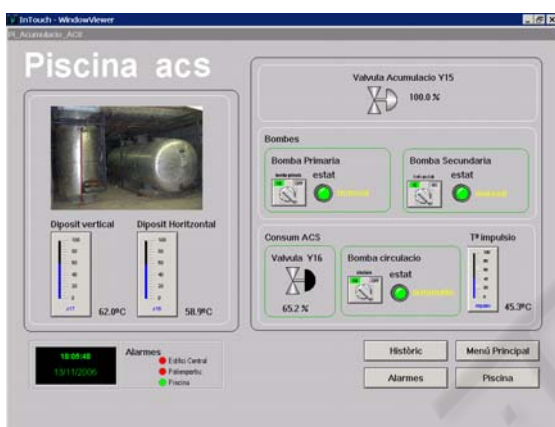Figure 8: Original Fronto and Rocodrom screen.

Figure 7: Piscina ACS revisited with changes in color indicator.

Figure 9: Fronto and Rocodrom revisited with changes in distribution indicator.

The SAF interface global evaluation is 3,4. The global evaluation is expressed in a scale from 1 to 5, so it is necessary to indicate SAF designer a set of important recommendations:

- revise the relationship between architecture, distribution and navigation indicators
- improve the feedback between interface and human operator in data-entry commands indicator
- improve the location of alarm indicator

With GEDIS guide is possible too to indicate SAF designer a set of important recommendations about graphical screen improvement. For example, the Piscina ACS screen can improve with a set of changes in color and text font indicators. Fig. 6 shows the original Piscina ACS screen and Fig. 7 shows revisited Piscina ACS screen.

A second example, the Fronton and Rocodrom screen can improve with a set of changes in distribution indicator.

Fig. 8 shows the original Fronton and Rocodrom screen and Fig. 9 shows revisited Fronton and Rocodrom screen.

5 CONCLUSIONS

In tasks of human supervision in industrial control room is habitual that an external engineer, - by means of the commercial programs Supervisory Control and Data Acquisition SCADA -, take charge of designing the supervision interfaces in function to the knowledge on the physical plant and the group of physical-chemical processes contributed by the process engineers.

Although standards exist about security in the human machine systems that impact in aspects of physical ergonomics, interface design by means of rules of style, it is remarkable the absence of the design of interactive systems centered in the user where the engineering usability and the cognitive

ergonomics can contribute significant improvements (Nielsen, 1993).

The GEDIS guide is an approach that tries to fill a methodological hole that joins the efforts of the systems engineering and the human factors for the improvement of the effectiveness of the human-machine system in industrial control room.

The application of the GEDIS guide to the study of cases contributes among other details the measure in form of indicators of aspects of interface design, the recommendation of changes for the improvement of the interface, and a global evaluation index that allows to quantify the current state of the interface regarding the future state after applying the correct measures.

The studied case presented shows a Spanish academic application, but with the same characteristics of an industrial project. With the GEDIS guide approach it's possible to perceive diverse anomalies and to propose improvements in the interface design.

Another current study with the GEDIS guide is the analysis of a sugar mill interface. The Sugar Technology Center (CTA) in Spain has been developed a training simulator to modeling and simulating the production process and the human operators' supervisory tasks. The simulator developed in this center is an example of full scale simulator, a type of simulator that reproduces the whole operating environment (Merino et. al., 2005). This simulator emulates the control room of a sugar mill. A series of object oriented modelling library tools are used to create each part of the sugar mill: diffusion, evaporation, purification, sugar room, boilers, dryer, and liquor storage.

In these moments the 4all-L@b Usability Laboratory of the Technical University of Catalonia is analyzing the GEDIS guide to simplify the number of indicators of the guide, to improve the evaluation method, and to promote the use of the guide inside the cycle of life of the software engineering, in this case in the early phases of the supervisory control interface design.

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