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Situation awareness measurement of an ecological interface designed to operator support during alarm floods

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ABSTRACT

Alarm summary interfaces are lists of chronologically sorted alarms used in oil producing supervision programs for decades. When a great number of alarms are activated in a small interval of time — that is, an alarm flood — alarm summary ceases to be as useful to understand the process situation. New alarm systems and interfaces are necessary to support operators' decision when dealing with such alarm floods. Situational awareness is an important concept for process operators when making decisions. The application of Ecological Interface Design concepts can lead to better interface designs, especially in unanticipated situations. The aim of this work is to verify the usefulness of a new ecological alarm interface, called Advanced System of Intelligent Alarms (SAAI, the Portuguese acronym). SAAI displays alarms prioritised in real-time with relevant graphical information on process conditions. Professional operators' situational awareness is measured when using either the SAAI interface, or the alarm summary interface, connected to a dynamic simulator running a model of an oil production process. Measurement techniques used include objective and subjective rating approaches, and a proposed technique. Operators' situation awareness for SAAI interface has shown greater values under all techniques used, compared to alarm summary interface. Although the new interface implied that operators would have to look also at an extra monitor, results show that their situation awareness improved on average, and that situation awareness might be less impaired under alarm floods.

Relevance to industry: Situation awareness plays an important role in operators' decision-making process. Alarm systems are critical in complex process operation, and alarm floods may impair operators' decisions. A new alarm ecological interface designed to maintain operators' situational awareness under alarm floods may mean an improvement in operation safety and efficiency.

1. Introduction

Operators are a line of defence when anomalies occur within processes like oil production or oil refining. A typical way of resorting to operators is alarming: when the supervision and control system detects an anomaly that might lead to a loss of control, it activates an alarm to call operators' attention. Operators, then, should have been trained to react accordingly to that alarm — and an alarm only makes sense if operators have enough time to respond to it (EEMUA, 2007). Technical conditions satisfied, operators can be accounted as a layer of protection for the process, as defined in risk assessment methodologies (CCPS, 2001) (Myers, 2013).

1.1. Alarm summary and alarm system interface

A common interface to see the active alarms is the alarm summary (Fig. 1): a window containing a list of alarms, sorted by time with the most recent one at the top. A priority may be assigned to each alarm, during the design process, and may be represented by a respective colour.

Sometimes, many anomalies occur concurrently — some independently of others, and some of them as a consequence of the others. In that situation, the activation of alarms may be faster than the operators' ability to respond to them — that is an alarm flood (EEMUA, 2007).

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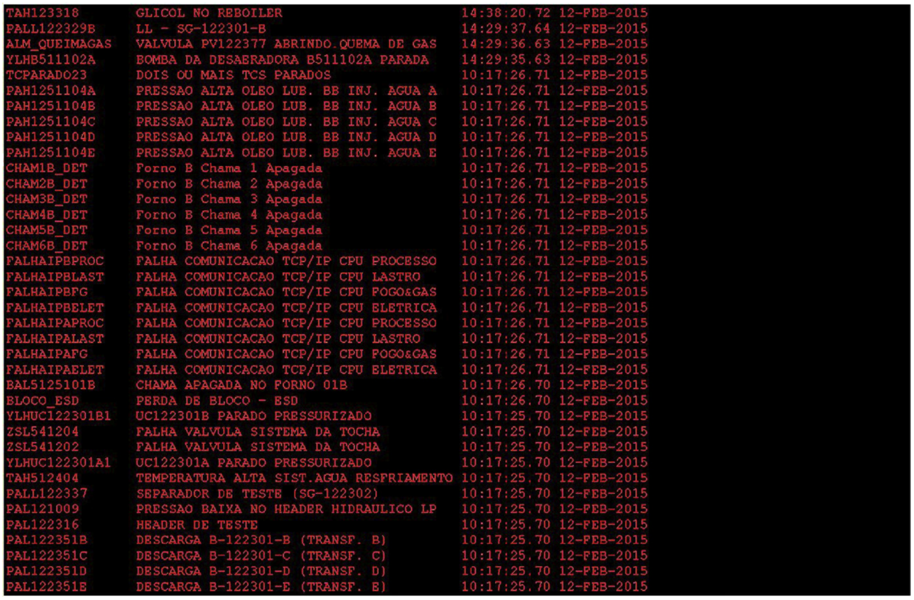

TAH123318	GLICOL NO REBOILER	14:38:20.72 12-FEB-2015
PALL122329B	LL - SG-122301-B	14:29:37.64 12-FEB-2015
ALM_QUEIMAGAS	VALVULA PV122377 ABRINDO.QUEMA DE GAS	14:29:36.63 12-FEB-2015
YLHB511102A	BOMBA DA DESAERADORA B511102A PARADA	14:29:35.63 12-FEB-2015
TCPARADO23	DOIS OU MAIS TCS PARADOS	10:17:26.71 12-FEB-2015
PAH1251104A	PRESSAO ALTA OLEO LUB. BB INJ. AGUA A	10:17:26.71 12-FEB-2015
PAH1251104B	PRESSAO ALTA OLEO LUB. BB INJ. AGUA B	10:17:26.71 12-FEB-2015
PAH1251104C	PRESSAO ALTA OLEO LUB. BB INJ. AGUA C	10:17:26.71 12-FEB-2015
PAH1251104D	PRESSAO ALTA OLEO LUB. BB INJ. AGUA D	10:17:26.71 12-FEB-2015
PAH1251104E	PRESSAO ALTA OLEO LUB. BB INJ. AGUA E	10:17:26.71 12-FEB-2015
CHAM1B_DET	Forno B Chama 1 Apagada	10:17:26.71 12-FEB-2015
CHAM2B_DET	Forno B Chama 2 Apagada	10:17:26.71 12-FEB-2015
CHAM3B_DET	Forno B Chama 3 Apagada	10:17:26.71 12-FEB-2015
CHAM4B_DET	Forno B Chama 4 Apagada	10:17:26.71 12-FEB-2015
CHAM5B_DET	Forno B Chama 5 Apagada	10:17:26.71 12-FEB-2015
CHAM6B_DET	Forno B Chama 6 Apagada	10:17:26.71 12-FEB-2015
FALHAIPBPROC	FALHA COMUNICACAO TCP/IP CPU PROCESSO	10:17:26.71 12-FEB-2015
FALHAIPBLAST	FALHA COMUNICACAO TCP/IP CPU LASTRO	10:17:26.71 12-FEB-2015
FALHAIPBFG	FALHA COMUNICACAO TCP/IP CPU FOGO&GAS	10:17:26.71 12-FEB-2015
FALHAIPBELET	FALHA COMUNICACAO TCP/IP CPU ELETRICA	10:17:26.71 12-FEB-2015
FALHAIPAPROC	FALHA COMUNICACAO TCP/IP CPU PROCESSO	10:17:26.71 12-FEB-2015
FALHAIPALAST	FALHA COMUNICACAO TCP/IP CPU LASTRO	10:17:26.71 12-FEB-2015
FALHAIPAFG	FALHA COMUNICACAO TCP/IP CPU FOGO&GAS	10:17:26.71 12-FEB-2015
FALHAIPAELET	FALHA COMUNICACAO TCP/IP CPU ELETRICA	10:17:26.71 12-FEB-2015
BAL5125101B	CHAMA APAGADA NO FORNO 01B	10:17:26.70 12-FEB-2015
BLOCO_ESD	PERDA DE BLOCO - ESD	10:17:26.70 12-FEB-2015
YLHUC122301B1	UC122301B PARADO PRESSURIZADO	10:17:25.70 12-FEB-2015
ZSL541204	FALHA VALVULA SISTEMA DA TOCHA	10:17:25.70 12-FEB-2015
ZSL541202	FALHA VALVULA SISTEMA DA TOCHA	10:17:25.70 12-FEB-2015
YLHUC122301A1	UC122301A PARADO PRESSURIZADO	10:17:25.70 12-FEB-2015
TAH512404	TEMPERATURA ALTA SIST.AGUA RESFRIAMENTO	10:17:25.70 12-FEB-2015
PALL122337	SEPARADOR DE TESTE (SG-122302)	10:17:25.70 12-FEB-2015
PAL121009	PRESSAO BAIXA NO HEADER HIDRAULICO LP	10:17:25.70 12-FEB-2015
PAL122316	HEADER DE TESTE	10:17:25.70 12-FEB-2015
PAL122351B	DESCARGA B-122301-B (TRANSF. B)	10:17:25.70 12-FEB-2015
PAL122351C	DESCARGA B-122301-C (TRANSF. C)	10:17:25.70 12-FEB-2015
PAL122351D	DESCARGA B-122301-D (TRANSF. D)	10:17:25.70 12-FEB-2015
PAL122351E	DESCARGA B-122301-E (TRANSF. E)	10:17:25.70 12-FEB-2015

Fig. 1. Illustration of an alarm summary.

When operating under an alarm flood, the alarm summary interface may impair an adequate operator's response (Laberge et al., 2014): the operators become unable to read the alarms and to deal with them because of the large number of alarms, the rate that the alarms are displayed, and the little time available to respond to all alarms. This may lead to operators having not enough understanding of the process status and, thus, underperforming in decisions, compromising efficiency and safety.

Several concurrent alarms mean that there will be concurrent tasks, each one with a limited time to be dealt with. Concurrent tasks create challenges to coordinate the execution of tasks (Xiao et al., 1996 apud Liu and Li, 2012). Simultaneous presentation (of multiple alarms, for example) presumably leads to higher information load. Operators (the task performers) show worse performance in information selection, and decision efficacy under time pressure, as in situations that need fast and accurate responses (e.g., troubleshooting processes) (Liu, and Li, 2012).

It has been observed that, when operating under an alarm flood, the operator may abandon the alarm summary interface, and turn to look at the operating windows, navigating through the process, trying to understand the scenario. The alarm summary is not of help anymore. Besides, the relative priorities decided during design and alarm system configuration may not be the relative priorities that should be assigned to the alarms in a given operating situation.

An alarm interface should help operators to understand the situation and to respond to the alarms, the ones of greater priorities first. Those priorities might be given in real-time, based on pre-assigned priorities. This alarm interface should be always visible, displayed on a dedicated monitor.

Operators would have to look at that extra monitor, besides the operating monitor, but this effort might bring improvements on their situation awareness (as defined in Endsley (1995a)) and decision making. That interface might turn operations safer and avoid shutdowns caused, at least in part, by the excess of alarms and high workload. Thus, there might be returns in safety and in revenues.

SAAI, a new alarm system that dynamically assigns real-time priorities to alarms, was developed by the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering of the Federal University of Rio de Janeiro (UFRJ/COPPE), in association with Petrobras, the Brazilian major oil company. SAAI is the Portuguese acronym for Advanced System of Intelligent Alarms. SAAI, besides assigning real-time priorities, displays the alarms with related process variables to help operator's situation awareness (SA). Ecological Interface Design (EID) (Rasmussen, and Vicente, 1989) was an approach of reference to SAAI interface design. An experiment to assess operator's situation awareness using SAAI was performed at a dynamic simulation environment, called AmbTrei (Portuguese acronym for Training Environment), where professional operators attend to refresher courses.

1.2. Situation awareness

Process supervising operators work in control rooms, which is a dynamic environment, since process variables and conditions vary, and operators are supposed to monitor the process and to actuate to keep it working adequately.

An important role in human decision making in a dynamic environment like process control and supervising is played by operator's situation awareness (SA). As defined by Endsley (1995a):

> "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future."

That definition express three levels of SA (Endsley, 2015) (Endsley, 1995a):

Level 1: Perception of the relevant elements of the environment. Process operators need to perceive process conditions. They need to perceive alarms and process data – the process variables values, like fluid levels of tanks, oil flow values, valve status, etc.

Level 2: Comprehension of data meaning. Operators need to integrate the disjoint data perceived to understand the current process situation. It is necessary to know if the tank levels are normal, low or high, if oil is flowing as it should, if valves are opening and closing, and, in synthesis, if the process is under control or not, and if it is attending the predefined goals.

Level 3: Projection in the near future. To make a better decision, operators need to foresee what the process status will be in the next several minutes, both in case no action is taken as well as a