Methodological Framework for Control Centres Evaluation and Optimization

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Abstract. Workers in control centers often pay attention to a large amount of information from several sources and must be able to identify, at all times, the system state to, in an emergency, take correct decisions. In this context, this article aims to present a preliminary framework for the development of a virtual reality simulator for the study of control centres in order to prevent Human errors occurrence. It will also be presented an example of the framework use to study the excessive number of alarms in a railway control centres. The paper discuss the next steps of this work, the evaluation of it sensitivity and the usability characteristics of the VR simulator inside to our framework.

Keywords: framework,virtual reality, control centre, simulator.

1 Introduction

Control centres are complex structures where the operator performs to maintain the routine of the process, being extremely important identify factors that may lead to errors that affect the process and define actions to reduce its occurrence. People in control must often pay attention to a large amount of information from a variety of sources and must be able to identify, at all times, the system state to, in a contingency, take correct decisions. While technologies for control and supervision make operator's work more efficient and proactive, the requirement for a rapid response to the high volume of information available in modern control centres may impose heavy demands on the operator's, influencing its performance. The amount of physical and mental resources that the operator applies when performing a specific refers to that task workload [1]. The workload resources that are available are fundamental concept when considering individual performance within complex systems [2].

Some factors have particular relevance in control centers as an intervening condition to failure. Aspects related to the physical, organizational and personal environment may interfere with the operator performance. Literature highlights problems,

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such as: high workload [2],[3],[4],[5],[6],[7] and temporal pressure [8]; fatigue and stress, regarding personal aspects; poor design equipment, temperature [9],[10]; lighting [11]; noises [10],[11], among other aspects. In this context, the motivation for the development of this paper comes from the occurrence of those problems in control centres that can lead to errors that result in accidents and incidents [9]. This article aims to present a preliminary framework for the development of a simulator for the study of control centres in order to prevent errors occurrence. It will also be presented an example of the framework use to study the excessive number of alarms in a railway control centres.

2 Framework

The preliminary framework (figure 1) of a Virtual Reality (VR) based simulator development for evaluation and control centers optimization can be summarized in four steps:

2.1 Data Gathering

This phase aims to characterize the control centers, in order to know the operation modes of devices, the working conditions and the major issues that may be responsible for accidents.

This phase is dependent on the nature of the study being undertaken. In experimental studies, data may be used from literature that report problems and conditions related to accidents occurrence. In field studies within organizations, data refer to real condition from the work tasks and activities analysis. It should, however, be, whenever possible, a balance between the data obtained from the literature and those obtained in a real work situation.

Diverse methods may be used to assess the control center work conditions. In particular, the following techniques can be applied: physiological measurements - to provide information about physiological states of the controllers; subjective rating scales - to provide information on how employees subjectively assess different aspects of work conditions and mental workload; performance assessment - to evaluate human mental and psychomotor performance under given work conditions, e.g. in order to assess decrements or variations in performance due to the effects of increasing mental workload; task analysis - to assess task elements, physical and psychosocial work conditions.

2.2 Problem Occurrence

This phase aims at defining the problem under study. Based on the analysis of data collected in the previous phase, the issues that might endanger persons, workers and control center safety are ranked. Relationship chains are also established among identified problems by defining a set of problems. At the end, relations are established among the problems and the characteristics of the control center.

This phase culminates in the identification of a problem or a set of interrelated problems and their association with the following aspects:

- Objects and equipment's size – (e.g. geometrical characteristics of objects and control center equipment);
- Environmental aspects – (e.g. lighting, noise, temperature, color);
- Personal aspects – (e.g. operational modes and level of stress, fatigue, motivation, operators experience);
- Organizational aspects – (e.g. workload, company polices, time pressure).

It is important to state which are only considered those aspects that have a significant impact on the consequences of the problems identified.

2.3 Simulator

This phase aims at developing a simulator to study the problems identified in the previous phase. Elements and variables number, to consider in modeling, are dependent on the type of problem to be studied and optimization sought. In this context, the simulator does not have the entire control centre and operations elements and functionality; it is only an adequate representation of the problem to be studied.

A simulator is composed of two components, the virtual environment and scenery. The virtual environment corresponds to the characteristics of the simulator that can be experienced by the participants, by sight, hearing or tactile, for example: furniture, machinery, types of control devices; displays with information; sound and lighting. It is very important that the virtual environment has consistent reactions to participant actions, allowing high levels of interaction.

The scenario corresponds to the narrative that will be presented to the participant and should be associated with the type of problem to be studied. Is usually associated with a framework in the form of a narrative, which includes the context of the problem occurring and tasks that must be performed by the participants. The scenario creates a quasi real environment of interaction and must allow the participant feel in the situation, so as to have a similar behavior to real situation. For this goal to be achieved, it is necessary that:

- The scenario has levels of detail consistent with the real situation;
- Be created a stream of increasing interaction, that in the beginning, the participant becomes involved with everyday tasks and at the end, is faced with the problem.

The simulations should include abnormal events, such as a fire, which cannot be reproduced in reality. Controlling the amount of time and intensity of the simulated events is a vital necessity for research [12].

Simulators have been used in recent and countless experiments in the railway sector, mostly in studies focused on train drivers. It is an important tool for evaluation, measure of performance or training, under normal conditions or at risk situations [12],[13],[14],[15],[16],[17],[18],[19], being relevant to answer issues about attention, situation awareness, workload, vigilance and fatigue [12].

There are different kinds of simulators, the most advanced represents the whole system and allow interactions very close to the one experienced in real systems, such as aircraft simulators. These models allow the training of pilots and the study of complex situations; however, its financial cost does not justify the development of such simulators for all situations, in particular, as regards control centers. An economic and effective solution is the use of Virtual Reality (VR), because allows the development of effective solutions and cost more bearable by organizations.

VR is an advanced computer interface that involves real-time simulation and interactions through multisensory channels [20]. It allows user to examine from different angles, three-dimensional spaces using three unique features of the RV, the so-called three "Is": Imagination, Interaction and Immersion.

- Imagination – is related to involvement meaning the degree of motivation for the engagement of a person with a certain activity. This involvement can be passive, where there is only the exploitation of the environment; or active, where there is environment interaction.
- Interaction – or manipulation, which is the system's ability to detect user input and respond to its real time commands.
- Immersion – is the feeling of being inside the virtual environment and not just feels watching from outside environment.

According to the official encyclopedic definition, VR is

“the use of computer modeling and simulation that enables a person to interact with an artificial three-dimensional (3D) visual or other sensory environment. VR applications immerse the user in a computer-generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn as goggles, headsets, gloves, or body suits. In a typical VR format, a user wearing a helmet with a stereoscopic screen views animated images of a simulated environment.” [21]

VR presents features such:

- Works with multisensory information (dynamic images, spatial sound, touch and force reaction, etc.) produced and manipulated in real-time;
- Prioritizes real time interaction;
- Requires high graphics, sound and haptics processing capability;
- Uses techniques and resources for graphic, sound and haptic rendering in real time;
- Promotes user actions in 3D environment;
- Uses special devices to multisensory interaction;
- Requires adaptation.

It is in this context that the framework presented in this paper is developed.

2.4 Solution

This phase aims to optimize the control centre characteristics that allow the improvement of the situation responsible for the problem. Thus, changes are implemented in the virtual environment characteristics (e.g.: type or number of commands, number and amount of information on the displays, sound information). Behavioral responses of the participants to these situations, allow checking whether, or not, there are improvements in modeled system performance. This information will be used to propose new changes in the simulator characteristics, until a satisfactory level of performance is achieved.

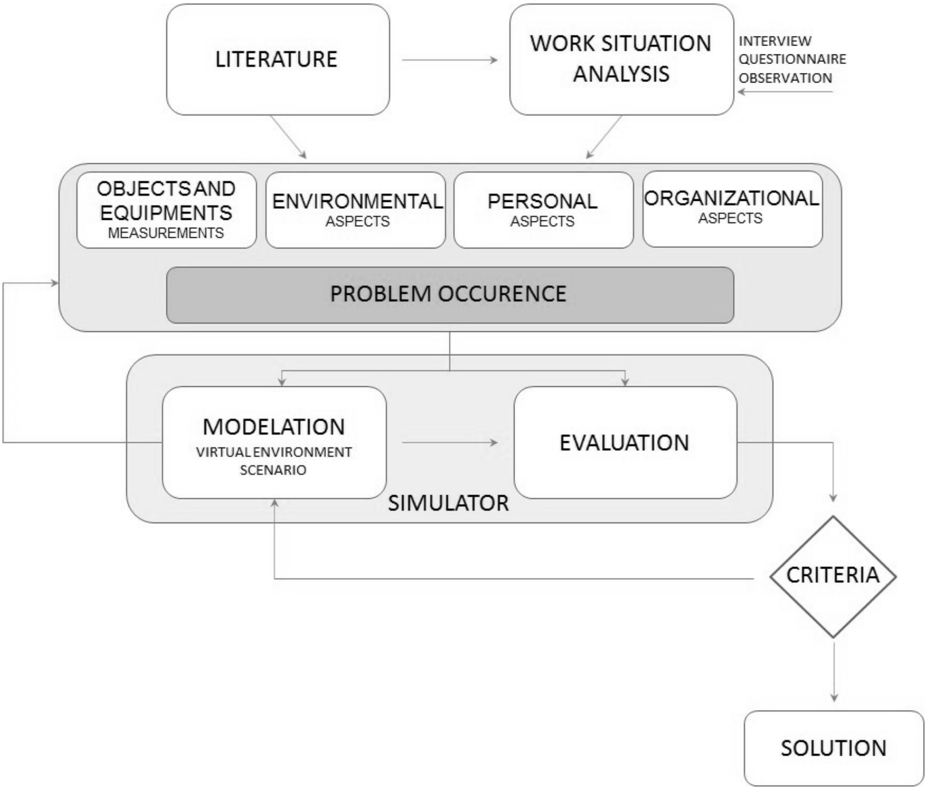

Fig. 1. Framework for Control Centres Evaluation and Optimization

3 One Framework Application: Alarms in a Railway Control Centre

Railway control centre operators actions is to maintain separation between trains on the network [22], then, his/her basic task is monitoring and supervising trains movement, in normal condition, and, intervention when problems occur. In these moments, it is necessary that the operator make the process back to normal using manual skills, mobilizing knowledge to develop strategies to act on diagnosis, fault detection, alarm management and problem resolution.

The context to be addressed refers to the physical environment, including noise and in particular alarms. Noise can arise from several devices installed in control centers, which, although not high, may cause disturbances [10], [11]; however alarms are the most common form of discomfort reported by operators [23].

In this item we will contextualize the use of framework with an example related to a problem that is reported in the literature in railway traffic control centres, the excessive number of alarms at certain times.

3.1 Data Gathering

In this example, we will focus first phase, using only the data reported in the literature.

Alarms are automatic devices that trigger due to some event with the aim to attract attention for the operator to intervene to solve the problem [23], [24], [25], [26]. Operators are notified of the existence of an alarm through different sources of information. Besides the beep, there are also visuals warning in the form of banners on the screen, warning light on the dashboard which is pointed to the location of the event, as well as information by phone. During a contingency period, increasing the amount and speed of alarms makes the alarm system not only useless but also creates an obstacle to the operator's ability to handle the situation [25]. Even under stress, the operator needs to analyze and interpret the alarm information quickly and securely, separating the important from those secondary and then to diagnose the cause of the problem and decide the actions to be performed.

Under normal circumstances about 10 alarms can occur per hour not meaning immediate operator intervention requirement because many of them may just be preprogrammed events confirmation. In emergency situations, this number can reach up to 200 alarms per hour [24] and remain active until the problem is solved [23]. In many systems the number of alarms is so high that operators ignore some of them, because it is physically impossible to properly analyze and interpret all. However, circumvent or bypass the alarm system contributes significantly to the worsening situation and leads to accidents [25], [27].

3.2 Problem Occurrence

“The alarm system must be reserved for events that require operator action” [28]. According to Hollifield and Habibi, one of the main reasons of alarm problems results from systems where alarms are configured without taking into account its main purpose which is to inform the operator that some action is necessary to prevent or mitigate a process disturbance. Problems arise during critical periods, where alarms are denser, where several alarms occur at the same time and among them occur alarms that do not give useful information about the detected anomaly or only indicate system status. In those moments false alarms will distract the operator and stop other tasks where the search for diagnosis is more difficult and requires the prioritization of information processing [29].

3.3 Simulator

What kind of alarm is best suited for the operator to make a decision in a critical situation?

Based on the following assumption will be made modeling scenarios and virtual environment will be taken.

Critical Situation Scenario. After a normal situation, a running over occurred on a line and consequent stoppage of the rail vehicle. Two more vehicles traveling in the same line and approach the vehicle is stopped. Two vehicles are urging to get in line, on grounds of delay. This triggers multiple alarms simultaneously.

The Elements Modeling in Virtual Environment. Considering the previous scenario is modeled a traditional control centre workstation, with table and with information line displays, control commands and audible alarms.

The behaviors to be observed correspond to the actions carried out to solve the problem.

Situation to Optimize. In the first phase is modeled the alarms typically used in control centres to evaluate the possible controllers performance degradation. After evaluating these results, strategies are developed for the modification of the alarms and evaluated the possible increases in operators' performance.

4 Conclusion

This paper described a preliminary framework for the development of a simulator for the study of control centers in order to prevent errors occurrence. An example was presented of the framework using a problem study in the railway control centers, particularly the alarm problem.

The next steps of this work will be the evaluation of it sensitivity and the usability characteristics of the VR simulator. The sensitivity of VR simulator shall be demonstrated by reproducing experimentally controlled variations of a problem. For example, a human error related with a high mental workload, associated with a particular work condition (i.e. number of actions to be performed, or the time constraints, under which the task has to be performed). In the VR simulator, this variation can be developed; creating conditions that can produce different degrees of mental work stress. The efficiency and user satisfaction is an important usability issue of the RV simulator. The efficiency is related with the effort required to create a VR simulator. In practice, we don't need to create a VR simulator with all characteristics of a control center situation, which involve huge resources that could disrupt the study. In addition, the

VR simulator should satisfy the requirements of the users. In this context is important to evaluate in an iterative way the performance of the simulator, against the user requirements.

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References

1. Cañas, J.: Ergonomía en los sistemas de trabajo. UGT-CEC. Granada (2011)
2. Wilms, M.S., Zeilstra, M.P.: Subjective mental workload of Dutch train dispatchers: Validation of IWS in a practical setting. In: Dadashi, N., Scott, A., Wilson, J.R., Mills, A. (eds.), pp. 641–650. Taylor & Francis, London (2013)
3. Balfe, N., Wilson, J.R., Sharples, S., Clarke, T.: Effects of Level of Signalling Automation on Workload and Performance. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 404–411. Taylor & Francis (2012)
4. Hayden-Smith, N.: The Future of Signaller Workload Assessments in Automated World. In: Dadashi, N., Scott, A., Wilson, J.R., Mills, A. (eds.), pp. 419–426. Taylor & Francis, London (2013)
5. Shanahan, P., Gregory, D., Lowe, E.: Signaller Workload Exploration and Assessment Tool (SWEAT). In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 434–443. Taylor & Francis (2012)
6. Weeda, C., Zeilstra, M.: Prediction of Mental Workload of Monitoring Task. In: Dadashi, N., Scott, A., Wilson, J.R., Mills, A. (eds.), pp. 633–640. Taylor & Francis, London (2013)
7. Zeilstra, M., Bruijn, D.W., Van Der Weide, R.: Development and Implementation of a Predictive Tool for Optimizing Workload of Train Dispatcher. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 444–453. Taylor & Francis (2012)
8. Read, G.J.M., Lenné, M.G., Moss, S.A.: Association Between Task, Training and Social Environmental Factors and Error Types Involved in Rail Incidents and Accidents. Accident Analysis and Prevention 48, 416–422 (2012)
9. Baysari, M.T., Mcintoch, A.S., Wilson, J.R.: Understanding the Human Factors Contribution to Railway Accidents and Incidents in Australia. Accident Analysis and Prevention 40, 1750–1757 (2008)
10. Nicholl, A.: Environmental Factors in the Control Room. In: Ivergard, T., Hunt, B. (eds.), 2nd edn., pp. 177–199 (2009)
11. Hénique, E., Lindegaard, S., Hunt, B.: Design of Large and Complex Display Systems. In: Ivergard, T., Hunt, B. (eds.), 2nd edn., pp. 83–130 (2009)
12. Maag, C., Schmitz, M.: Assessment of Train Drivers' Performance in a Driving Simulator. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 136–145. Taylor & Francis (2012)
13. Albrecht, T., Gassel, C.: Efficient Control of Passenger Railways: Testing Advice and Information System in a Driving Simulator. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 117–125. Taylor & Francis (2012)
14. Egea, B.G., Holgado, P.C., Suárez, C.G.: Human Factors Integration in Rail Simulators. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 188–193. Taylor & Francis (2012)

15. Hammerl, M., et al.: From a Testing Laboratory for Railway Technical Components to a Human Factors Simulation Environment. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 154–164. Taylor & Francis (2012)
16. Naweed, A., Hockey, G.R.J., Clarke, S.D.: Designing Simulator Tools for Rail Research: The Case Study of a Train Driving Microworld. Applied Ergonomics 44, 445–454 (2013)
17. Rentzch, M., et al.: Simulator Tests of a Harmonised European Driver's Desk. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 146–153. Taylor & Francis (2012)
18. Wada, K., Ueda, M.: Emotional Responses to Trouble Events on a Train-Driving Simulator. In: Human Factors and Ergonomics Society 56th Annual Meeting, pp. 1997–2001 (2012)
19. Yates, T.K., Sharples, S.: Determining the Effect of Simulator Configuration in a VR Train Driver System. In: Wilson, J.R., Mills, A., Clarke, T., Rajan, J., Dadashi, N. (eds.), pp. 107–116. Taylor & Francis (2012)
20. Burdea, G., Coiffet, P.: Virtual Reality Technology, 2nd edn. John Wiley & Sons (2003)
21. Encyclopædia Britannica, `http://www.britannica.com/EBchecked/topic/630181/virtual-reality-VR`
22. Patrick, C., Balfe, N., Wilson, J.R., Houghton, R.: Signaller information use in traffic regulation decisions. In: Dadashi, N., Scott, A., Wilson, J.R., Mills, A. (eds.), pp. 409–418. Taylor & Francis, London (2013)
23. Bransby, M.L., Jenkinson, J.: The Management of Alarm System: A Review of Current Practice in the Procurement, Design and Management of Alarm System in the Chemical and Power Industries. Health and Safety Executive (1998)
24. Dadashi, N., Wilson, J.R., Golightly, D., Sharples, S., Clarke, T.: Practical use of Work Analysis to Support Rail Electrical Control Rooms: A Case of Alarm Handling. J. Rail and Rapid Transit. 227, 148–160 (2012)
25. Hollifield, B.R., Habibi, E.: The History and Nature of the Alarm Problem. In: Hollifield, B.R., Habibi, E. (eds.), pp. 7–12 (2007)
26. Huang, F.-H., et al.: Evaluation and comparison of alarm reset modes in advanced control room of nuclear power plants. Safety Science 44, 935–946 (2006)
27. Hollifield, B.R., Habibi, E.: How do you Justify Alarm Management? In: Hollifield, B.R., Habibi, E. (eds.), pp. 13–18 (2007)
28. Hollifield, B.R., Habibi, E.: What Should be an Alarm? In: Hollifield, B.R., Habibi, E. (eds.), pp. 19–26 (2007)
29. Woods, D.D.: The Alarm Problem and Directed Attention in Dynamic Fault Management. Ergonomics 38, 2371–2393 (1995)