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Electrical System Operator Training Evaluation

A sistematic Approach

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Abstract: Despite the large investment in the development of tools to support training in the operation of electrical systems, such as simulators, little has been invested in evaluating training effectiveness. To increase the effectiveness of training and minimize the workload imposed on tutors; this paper presents a tool for supporting the evaluation of effectiveness of the training programs conducted in simulators. This tool analysis the log file of the training session, which is typically stored in a database associated with the simulator. This paper presents the tool and a case study in which it was validated.

Keywords: Operator Training, evaluating task, simulator.

Introduction

The quality of an industrial system operation is directly linked to the quality of the training provided to its operators. Evaluating training efficacy should result in identifying gaps in the skills and knowledge acquired by the operators. Currently this kind of evaluation relies solely on the monitoring of practical activities (observation), during which target tasks are performed by trainees, thus being the most commonly adopted by companies.

In spite of the large investments to develop tools to support training in electrical system operation, such as simulators, it becomes evident the weak point on training evaluation. To increase the training effectiveness and minimize tutor workload this paper proposes in a tool which aims to support training evaluation, provided that there is a time stamped data log registering all of the actions performed, in a database.

This article proposes to enhance the training evaluation process analyzing

The log file is analyzed by the proposed tool, in order to check specific aspects of operator performance, by comparing with a prescribed list of tasks. The tool allows for performance comparison between different individuals in the same training and of the individual with himself in different training sessions. The results should provide more objective metrics when evaluating training effectiveness. As a result, there will be stronger basis for the proposal of changes in training strategies such as exploring different scenarios, or even changes in methods, techniques and contents to be explored during training sessions.

This article is organized in 5 sections, as follows. It starts with an overview of the research context and a concise description of operator training assessment in electrical systems. This is followed by a brief presentation of the Training Assessment Tool (TAT) followed by Case studies performed in order to validate the tool. It concludes with Results discussion and proposals for future work.

Research Context

With technology development there was a rise in interaction complexity and the cognitive demands on users of automated systems. The higher rate of accidents caused by human error is highly correlated to the amount of information to be handled and system usability, reinforcing operator’s training as a means to prevent or reduce error incidence.

In the literature [5] simulator based operator training can positively influence the quality system operation. These also state that to reach training effectiveness it is necessary to reach a minimum of training requirements regarding the scenario realism and simulators’ fidelity to the real environment. The realism of the training situation regards the communication between control centres; and influences the quality of decision making in stress situations. However tutors must evaluate operator performance based on real time training monitoring. The volume of details to observe, register and analyze during training imposes a high demand on these individuals and less precision on the task, since many of these details might be lost preventing later analysis.

Although the literature a number of work stating the relevance of simulator training [4], [6], [7] there aren’t matching numbers which discuss their effectiveness. The vast majority suggests employing questionnaires and checklists when observing operators during training.

Many are the benefits mentioned regarding process simulation based training [3], such as:

- A typical 30% reduction in training time of an experienced workforce;
- Enables actual unit operation problems to be depicted and the re-creation of common and unique events;
- Speeding up or slowing down training pace in order to build on existing skills and boost operator confidence;
- Refreshing and reinforcing operator best practices.

Training Assessment in electrical systems

The tool proposed on this paper is independent of training platform, since it depends only on the activity log analysis, which must be stored in a database- a requirement met by most simulating tools. Two of its major users are the electricity company CHESF (Hydroelectric Company of São Francisco) and ONS (National Operator of Electrical System). In this article two simulating platforms were used. The first one: Simulop, is a simulating system developed for the electricity industry in Brazil. The second one: SimuLIHM, is a simulating tool developed at the Laboratory of Human Interface (LIHM) at the Electrical Engineering Department at the Federal University of Campina Grande (UFCG), was develop to support studies on the human error [2].

In both cases, assessing operators under training is still performed by the tutor unassisted by tools. It consists on observing the operators during training and issuing an appraisal, based on checklists used during the observation. The appraisal typically identifies errors and proposes further training. On the other hand, the evidence to support diagnosis may not be available later. On the other hand, the appraisal based on the log data supports comparative analysis by redeeming the history of training, already undertaken.

It follows a brief description of the simulators used in the research here described.

A. Simulop

The Electric Power Research Institute (EPRI) has developed an Operator Training Simulator (OTS) that is the engine for many of the power systems simulators currently in use by electricity utility companies. OTSs replicate the behavior of a power system and respond to changes in operating conditions due to events. For instance, due a power line fault, power flows and voltages are automatically recalculated, in real time, to simulate what would happen if the same event were to occur in the real system. Figure 1a illustrates Simulop human interface. The simulator consists of the OTS replacing the real system connected to the Supervisory system so that the trainees can interact with the same user interface as used in their real tasks.

B. SimuLIHM

This 3D virtual reality simulator was conceived to support operator training in electrical systems substations. The operator can develop skills by performing routine tasks or contingency scenarios (identifying faults and restoring the system). This simulator offers two alternative interfaces: a 3D replica of the working environment and the supervisory system screen displaying the system electric diagram, as shown in Figure 1b.

a

b

Figure 1. a. Simulop human Interface and b. SimuLIHM human interface

Training Assessment Tool (TAT)

According Embrey [10], task analysis is essential when analyzing the human error in order to eliminate it. The tool here proposed assists the tutor in assessing operator performance during tasks performance, confronting during its analysis the task performed with the task originally prescribed. The analysis procedure compares the performed task with predefined quality requirements and allows for statistical studies based on the historical data analysis to support the proposal of complementary training.

Besides analysing the log data, TAT can analyze strategies adopted during task and temporal parameters such as time taken to perform task and the duration of each action within the task. The discrepancies found between the prescribed and the performed tasks are diagnosed according to an error typology which resulted from a study of the human in electrical systems operation. The analysis results are expressed in textual and graphic format, on screen or in a report with a detailed account of the operator achievements.

The tool's architecture, illustrated in Figure 2, is composed of three modules: data base log extractor module; log analyzer module and results visualization module. It was developed using the Java programming language [8], whereas its database was developed in Microsoft SQL Server 2012 [9]. The communication between the database and the application modules was developed using the JDBC (Java Database Connectivity) library.

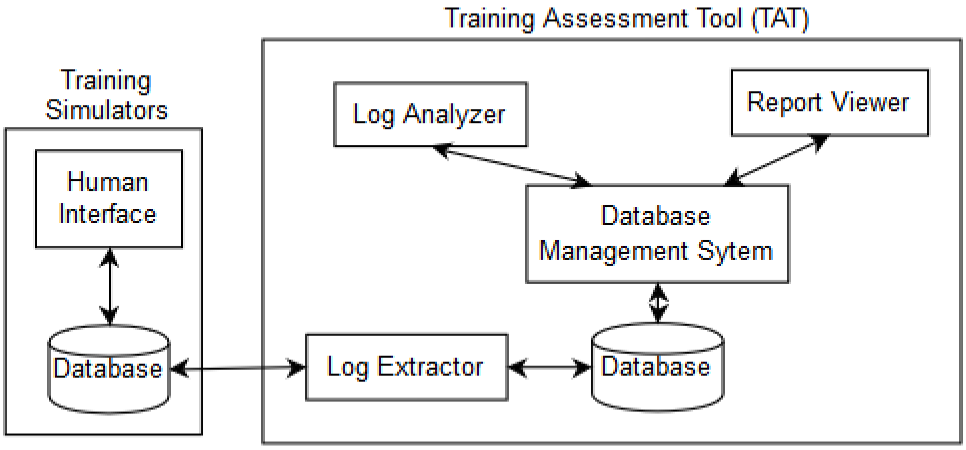

Figure 2. TAT's Archictecture

A. Log Extractor Module

Extracting results from a simulator database implies in using a parser to convert the data format adopted in the simulator database to that of the TAT database. This parser's function is to couple the tool (TAT) to the simulator, interpreting and mapping the log data into the tool's database.

Once the log has been mapped it will be possible to extract the log information, regardless of data format and type. The data consists of time stamped action and the corresponding action result, expressed as the final state of a system object and its name. In TAT's current version the parser can map from Microsoft SQL and MySQL databases. Nonetheless, a change of database will require the queries adaptation and the use of an appropriate communication library. Therefore this development effort is low, since there is already a query's model. This model supports the adaptation to other simulating tools provided that there is a time-stamped log available on a database.

B. Log Analyzer Module

This module is responsible for comparing trainee's performance with training efficacy requirements such as: time taken to solve a problem and error rate given the expected sequence of actions to be preformed. The performance requirements are used during task analysis, as explained in [11]. For this module to work, the tutor must describe the list of prescribed actions with which the algorithm will identify and classify the human error during log analysis. The errors are classified in one of the following seven categories [2]: correct action performed on the wrong object; skipped action in the prescribed task sequence; inappropriate action (outside the task context); added action, according to the prescribed task; incomplete task sequence; altered sequence; inappropriate timing.

C. Results Viewer Module

This module is used to produce the analysis results presentation. As illustrated in Figure 4, the tool also offers support for training management. That is, identifying the most common mistakes during training and following the history of operator performance it provides elements to support recommendations for further training, and keeping a training calendar. By comparing operators' performance, it is also possible to propose more adequate scenarios and to identify if the minimum requirements to be considered apt for work have been achieved.

Figure 3 illustrates the data flow in the tool, which starts by extracting the log data from the simulator database. This is done by the log extractor and its parser to save it afterwards in the tool's database. In the next step, the tutor chooses which training to analyze and TAT processes this training saving the assessment results in its own database. The flow ends with the display of results of the comparison between the logged data with performance requirements in a group of trainees.

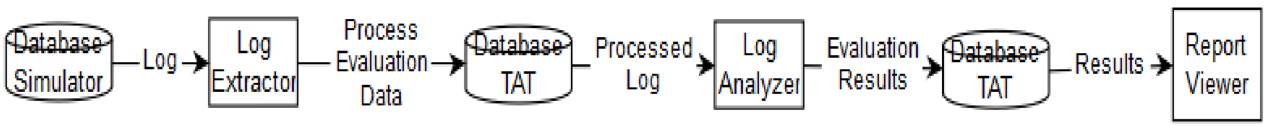

Figure 3. TAT's data flow

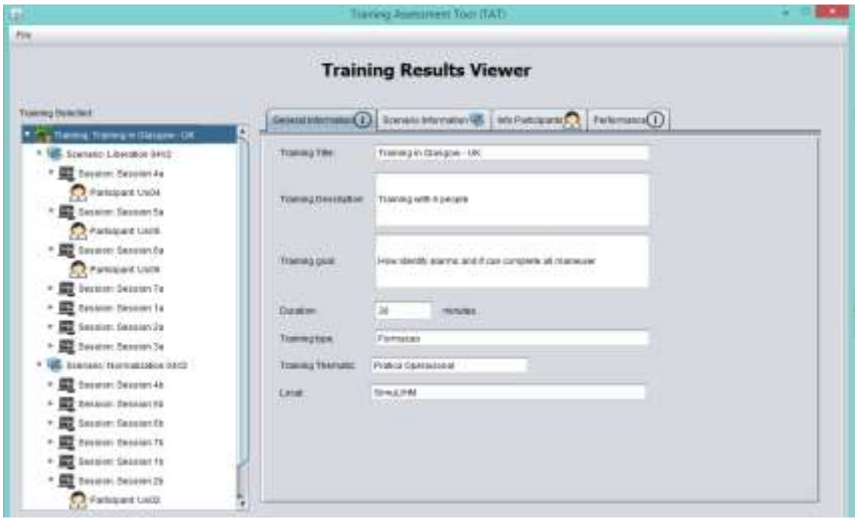

Figure 4. TAT's result Viewer

Case studies – Assessing training

Two experiments were conducted in order to assess the efficacy and adequacy of TAT. The first Experiment was conducted at Strathclyde University in the UK and the second Experiment was conducted at UFCG with data obtained from a training conducted by a Brazilian electricity company.

A. Collecting data during *training*

Experiment 1, consisted in conducting training sessions, with participants using SimuLIHM. During the experiment, which consisted of individual session with one participant at a time, these were asked to perform two tasks, following a script. Table I illustrates an excerpt from the script given to participants, which consists of a sequence of actions. Observers followed the participants' activities and events programmed to happen during the session.

TABLE I. EXCERPT FROM A SCRIPT MANOEUVRE

1	Liberation of breaker 14V2		Time
1.5	CGD	Close a circuit breaker 34V2-6, in panel 04V2	:
1.6	CGD	Put switch 43 -14D1 in the position 'transferred', in panel 14D1	:
		Alarm in panel 12A4, will be activated (participant must locate it and silence it)	:
1.7	CGD	Put switch 43 -14V2 in the position 'transferred', in panel 04V2	:
		telephone will call (participant must silence it)	:

This experiment aimed to assess the results from participant performance during the task. It consisted of immersing the participant into an electricity substation operation work environment and later analyzing the performance through database log extraction and analysis. The experiment was performed by seven participants of both genders, with similar background knowledge on the task context and on the tool. Participant data concerned qualitative and quantitative performance achieved during task execution.

Experiment 2, consisted in extracting and analyzing data from a real training log performed at an electricity company using the Simulop tool. This experiment validated the extraction of log data from a simulator employed by the industry in a real training situation. The training consisted in handling real contingency situations when real operator had to identify the problem, and restore the system within time constraints and quality restrictions, following a prescribed set of task steps.

B. Measuring Task Performance

Table II summarizes the errors incurred during the task 01 and 02, in Experiment 1. Task 01 consisted in releasing a transmission line for maintenance. The operation consists in opening and closing switch breakers in order to release the line. The experiment participants had a script available describing the procedure, detailing the sequence of steps involved in this operation. Participants were given 20 minutes to complete this task, and only one, participant 01 (P1) exceed the estimated time. Task 02 consisted in normalizing the use of the line after maintenance services. The participants were given 10 minutes to complete the task, since this procedure consisted in the reverse of the previous one, and thus they were familiar with the simulator. As illustrated in Table II, no participant exceed the estimated time in task 02.

Table I1: Summarizes results obtained in Task 1 and Task 2

		P1	P2	P3	P4	P5	P6	P7
Task 1	Error rate	4	7	1	3	0	3	2
	Error type	1	1,3,6	1	1,3,4	-	1,4	1,4
	Task duration (min:ss)	23:02	17:20	17:31	10:17	12:00	19:00	15:03
Task2	Error rate	0	1	2	4	0	1	4
	Error type	-	1	3	3,4	-	4	3,4
	Task duration (min:ss)	03:44	04:34	06:41	08:00	07:00	08:00	06:58

C. Presenting Assessment Results

One of the metrics employed in assessing the training effectiveness is the Error Rate during a task performance. Figure 5 illustrates for Experiment 1, the participants' Individual Error Rate compared to the Average Error Rate achieved by the group, in both tasks. This result gives evidence that participants P1, P4 and P7 need further training to level with the group's performance.

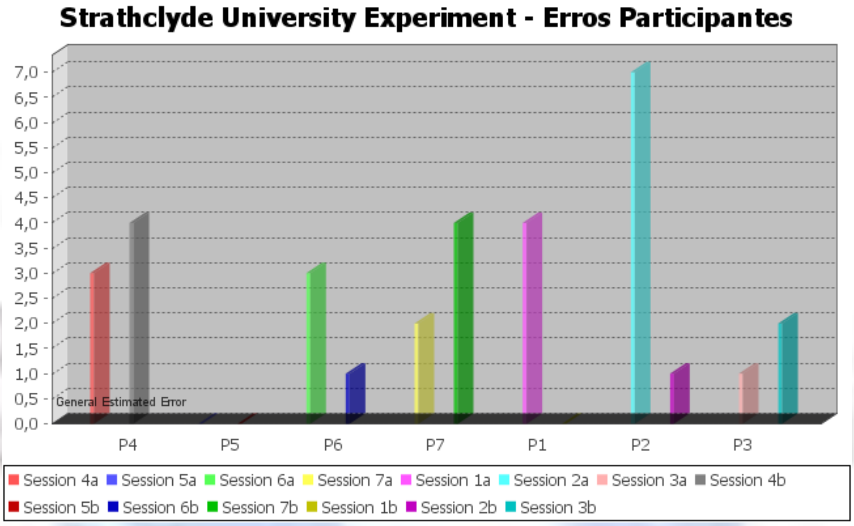

Figure 5. Participant's Error Rate

Another result provided by the tool is illustrated in Figure 6. It consists of the distribution of errors according to the error typology adopted. As it is shown, the type with the highest incidence: 38%, is "performing the correct action on the wrong object". This type of error often occurs due to lack of operator's attention, or due to information overload and con be a combined effect aggravated by low usability of the human interface.

Figure 6. Error type distribution

The data gathering for Experiment 2, was done by the electricity company staff, therefore the authors only had access to the log file from one session when the simulator was employed in the training of two operators. The training session consisted in performing a contingency task which resulted in a simulated power cut due to a fault on a circuit breaker. The operators needed to identify the problem, isolate the faulty area and restoring the power. In order to analyze the log file acquired from the simulator database, it was necessary to enter the description of the prescribed task. The analysis result makes evident that in this case, the operator performed all the task correctly and within the estimated time. The importance of this experiment was to verify the adequacy of TAT for analyzing log files from a variety of simulating tools including the ones used by the electricity industry in real training.

Results Discussion

In Experiment 01, the tool results were compared with the results from those achieved with the observation of participants done in real time and those form the analysis of recorded video during the experiment. In such simple task all results compared (task time, error distribution, etc.). Nonetheless the toll log analysis is faster, and will be more precise particularly in trainings which issue a large volume of information. Using the tool to analyze quantitative data, res=leases the tutor to focus on qualitative data, raising the quality of the assessment. The tool also proved very useful in quickly generating reports which can be enhanced by the tutor and also to be used during training debriefing, immediately after the training session.

The tool's database also facilitates storage of the results of individual training and group training for further training planning. The assessment tool applied to the log of routine tasks allows for continuous monitoring and unassisted assessments. Its modular architecture allows extending functionality and algorithm improvements in order to account for new types of error. With TAT it is possible to set training targets for groups and individuals setting performance standards within companies.

The tool can be employed in other contexts of training, provided that there is a log to be analyzed such as petrochemicals, textiles, shipbuilding, among others. As future work the authors intend to extend the assessment criteria to include other aspects such as the quality of communication between operators and in different installations and operating centres, which is also considered relevant for the quality of service.

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