# Assistance to trainers for the observation and analysis activities of operators trainees on Nuclear Power Plant Full-Scope Simulator.

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**Abstract— This article focuses on the professional training of operators of Nuclear Power Plants (NPP) on Full-Scope Simulators (FSS). In such context, observation and analysis of the individual and collective interaction of the trainees are critical and particularly difficult. The objective of our work is to propose models and tools to help trainers observe and analyze trainees' activities during preparation and debriefing. For that purpose, our approach consists in representing the actions of the operators and the simulation data in the form of modelled traces. These modelled traces are then transformed in order to extract higher information level. Trainers can visualized the different levels of trace to analyze the reasons, collective or individual, of successes or failure of trainees during the simulation. In order to validate our approach, we have developed the prototype D3KODE based on the trace model and transformation that we proposed. This prototype was then evaluate according to a protocol based on a comparative method in the context of several experiment conducted with a team of experts, trainers and trainees from EDF Group.**

***Keywords- Modelled Traces; Transformations; Exploration Trace-Based Systems Framework; Full Scope Simulator; Observation and analysis help; Training; Nuclear Power Plant***

## I. INTRODUCTION

This work focuses on the observation and analysis of learners' activities in a situation of professional training. Specifically, we focus in this article on full scale simulators designed for training of operators of nuclear power plants [6] [1] [10]. In this context, the observation and analysis of individual and collective interactions of trainee operators is a dense activity. Indeed, during each simulation session, the instructor runs the simulation scenario, observes behavior of trainees, drives the simulator based on the actions performed by trainees and fills the *observation balance* sheet to prepare the debriefing. Observation balance sheet contains a set of expected operations that trainees should be able to satisfy, like ensure continuity of service or the teamwork (see for example the Annex G of [8]).

In order to decrease the cognitive overload inherent in these tasks, the nuclear power plant simulators have several tools to record the operator activities such as logs, video, telephony, etc. Data collected by these tools enable instructors to return, during the debriefing phase, to the difficulties encountered by operators in order to provide solutions to improve their practices. Nevertheless, these data are difficult to use for several reasons:

- Data stored in the logs are very low, so it is difficult to analyze it manually to extract high level information reflecting the behavior of trainees,
- The amount of data collected by these tools is so important that it is very difficult to analyze manually. For example, a simulation session of one hour can generate more than 5000 events traced,
- The synchronization of these data, of different types (video, sound and logs), is also difficult and expensive. Indeed, the data is stored in different files and do not share the same timeline.

The objective of our work is to propose models and tools to help trainers observe and analyze trainees' activities. Specifically, It consists in supporting the trainer in the preparation phase of debriefing. Therefore, our approach is based on the representation and treatment of traces of activities. Generally, a trace is defined as a history of user actions collected in real time from his/her interaction with the system [2] [3] [5]. Formally, a trace is a set of observed elements temporally located where each observed represents an interaction between the user and the system.

In our research context, traces represent the activity of trainees on the simulator. We add more calculated data of the simulator to create the simulated process. Indeed, the simulator also leaves traces of its own activity. To facilitate the treatment and analysis of these traces, we developed a system to:

- retrieve data collected by the simulator (logs, annotations video and sound) and represent them in the form of modelled traces,
- transform these traces, using a rule-based system, to generate other traces of a higher level of abstraction, especially for verify if expected operations have been achieved or not,
- visualize the different levels of trace to enable trainers to analyze the reasons, collective or individual, of successes or failure of students in order to prepare and conduct the debriefing.

This work is part of a research project conducted in partnership with UFPI (Training Unit Production Engineering) of EDF group. The main activity of UFPI (over

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700 trainers, 3 million hours of training per year) is to provide professional training courses for staff working in the domains of power generation (nuclear, fossil-fired, hydraulic). Among its formations, the UFPI trains operators to drive nuclear power plants. For this, the trainers of the UFPI organize simulation sessions on full-scale simulators. This project aims to facilitate the debriefing and analysis phases of simulation sessions by providing tools that allow trainers to analyze the traces of trainees.

This article is organized as follows: section 2 presents related works on observation and analysis systems of operators activities on full-scale simulators for nuclear power plants. Section 3 describes the application context of our work concerning the training of operators of nuclear power plants of the UFPI. Section 4 presents the principle of our approach of observation and analysis activities of the operators trainees. Section 5 details the models of trace and transformation that we propose. Section 6 provides the tool we have developed and the evaluation conducted to validate our contributions. The last section is devoted to a conclusion and perspectives.

## II. State of the Art

Despite of the important needs in helping trainers to observe and analyze trainees' activities on NPP FSS, there are few publications on this specific subject. This could be explained by the confidentiality and the sensibility of this domain. Among systems and methods used for observation and analysis, we can mention [7], [9] and the synthesis of [10].

The system SEPIA [7] is a computer training system based on artificial intelligence concepts for EDF operators training. SEPIA allows the analysis of trainees' behaviors on simulator in order to help them in learning process. Such system brings trainers a help to prepare and conduct the debriefing with trainees. For this, SEPIA proposes to compare the actions of trainees with the expected behaviors. In [9], the authors propose a "Simulator Training Replay System" developed as a supporting tool for instructors to carry out effectively pre- and post-studies of operation training in classrooms. This system can synchronously replay FSS training exercises using in real time video, plant behavior and operators response data. It can also helps instructors to make trainees understand the interrelationship between plant behavior and their operating actions. [10] present a review of methods related to assessing human performance in NPP control room simulations. This methods are based on analyze of data which are collected by direct and indirect observation. This article identifies 6 categories of data collection methods for assessing performance: direct observation, automated computer logging, recordings from physiological equipment (e.g., ECG, eye tracking equipment, etc.), self-report techniques (i.e., surveys and questionnaires), protocol analysis and structured debriefs, and application of model based evaluation.

All these systems are used to store data collected during or after the simulation in order to help the trainer to analyze the achievements of trainees operators and prepare the debriefing or making the trainees having a reflective analyze of their own activities by viewing their traces. However, these systems do not represent the activity of trainees at different levels of abstractions. Such systems are not either opened as far as the knowledge used by these systems are static. The trainers are not allowed to insert their own observation and analysis knowledge. To provide flexibility and scalability to this analysis, we propose an approach based on rule, which allows representing the activities' traces of trainees at different levels of abstraction. The principle of this approach is presented in the section 4. In the following section, we present the project we conduct with UFPI of EDF Group.

## III. Application Context: Simulator Training in UFPI of EDF Group

Within the Engineering Production Department (DPI), the UFPI provides professional agents in the conduct and maintenance of power generation facilities. In particular the UFPI provides training and the capacity preservation of operators of nuclear power plant. As such, this unit includes response means and assistance for the design and implementation of skills development schemes. Each Nuclear Power Plant has a Full-Scope Simulator, exact replica of the control room of the plant. For many years, the UFPI organizes for its trainees the simulations sessions on Full-Scope Simulators. These sessions are essential to the formation and maintenance of operator skills.

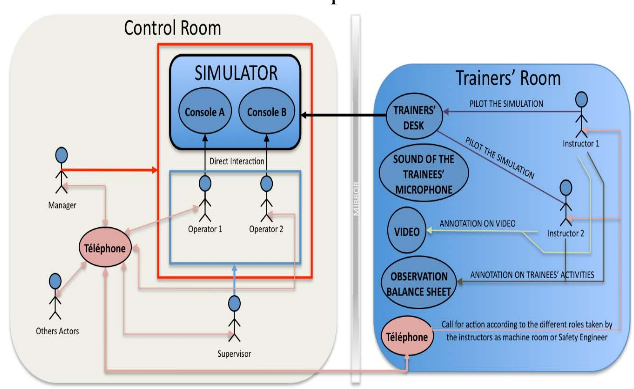


Figure 1. Description of the simulation environment

As shown in Figure 1, during the simulation session, the trainers (one or two according to the type of formation) must pilot the simulation and observe with different means trainees' actions. The trainees have to realize a *transitory*. A transitory represent the set of actions that make the simulator move from an initial physical state $e_0$ at the moment $t_0$ to a final $e_n$ state at $t_n$. For this, the trainees must drive the simulator according to expected operations organized in *Pedagogical Objectives Family*. Among these objectives we can cite: know and monitor the installation, drive the installation, assure the continuity of service, work in team, etc.

The training and improvement sessions on the NPP FSS of EDF consists in several important phases. Among these phases, we find:

*1)* Welcome and briefing of trainees: During this phase, trainers present the simulation scenario to the operators trainees and specify the role of each of them (supervisor, operations manager, manager, etc..)

*2)* Realization of the transitory. For this, operators must implement procedures for the scenario and the various situations encountered during the simulation,

*3)* Analysis of the simulation: at the end of the simulation, the trainers prepare the phase of debriefing. For this, they share observations (notes and balance sheet). In this phase, trainers verify if expected observations and actions were realized or not. Trainers analyze also the difficulties met by the trainees during the exercise, as well as the reasons of succes or possible reasons of failure (individual or collective).

*4)* Debriefing and synthesis of the session: The trainer(s) report the observations and discuss with trainee(s). At the end of the debriefing, trainer(s) give an appreciation and underline progress to be made.

The project we conduct with UFPI has two objectives. The first one, in the short term, focuses on the development of a tool for observation and analysis of the trainees' activities to assist trainers in the preparation of the debriefing phase. The second one, in long term, concerns the implementation of a system to feed Experience Feedback. Through Experience Feedback, trainers try to understand good or bad practises in order to improve contents of the future training courses at a national level.

The work we present in this paper addresses the first objective. We have developed a system to retrieve data collected during the simulation (logs, annotations and video and sound) and store them in modelled traces, transform these traces to extract high level information on the activity of trainees, and finally view these traces in an interactive way with the trainer.

In the following section, we present the general principle of this system.

## IV. Principle of our approach

Our research is based on the activity traces work developed by the SILEX[1] team [5]. A Modelled Trace, noted "M-Trace", is a set of observed elements. We call observed element, noted "obsel" any structured information generated from the observation of an activity [11]. In our research context, the activity we observe is a training simulation on a NPP FSS of EDF. The obsels we collect are the result of interactions between users (trainees and trainers) with the FSS, and the simulation of the NPP process itself. Formally, each observed element has a type, a label and a time stamp in the M-Trace. According to his type an obsel can have a set of attributes/values, which characterizes it. An obsel can potentially be in relation with other obsel of the same "M-Trace" through "relation type" defined in the Trace Model. The Trace Model defines the types of observed elements (i.e the attributes that characterize them) and the types of relationships they can maintain. A Modelled Trace is then a structure of data (obsels and relations) explicitly associated with its trace model.

Modelled Traces are managed with a Trace-Based Management System (TBMS) [5] [2] [3]. The TBMS is responsible for managing the storage of traces (rights management, database...) and their transformations. A Transformation process performs transformations on M-Traces like applying filters, rewriting and aggregating elements, computing elements attributes, etc. so as to interpret and abstract M-Trace.

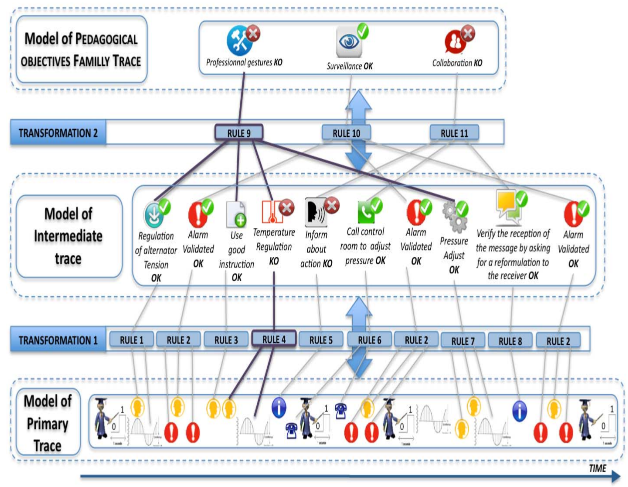


Figure 2. Principle of analysis by transformation and visualization of trace

For reasons we have explained above, the data collected by the simulators are difficult to analyze. It's why we distinguish three levels of m-traces corresponding to different levels of abstraction, namely:

- *The Primary M-Trace* whose observed element arise from data collected by the sources of the simulator such as video or the logbooks of the simulation (user's interaction and the simulator process)
- *The Intermediate M-Trace*, which represents the first level of expected obsels that trainees have to realize and trainers to check as adjusting a pressures, or validate an alarm. This trace offers a high abstraction level that facilitates observation and understanding of activity for the trainers.
- *M-Trace of Pedagogical Objectives Family.* This higher M-Trace level shows obsels that describes "pedagogical objectives family" (realized or not) as expressions of the expected trainees' capacities like "know and monitor the installation", "drive the installation", "assure the continuity of service", "work in team", etc.

These different levels of m-traces are obtained by applying rule-based transformations. As shown in figure 2, each obsel belonging to a trace of level *n* is in relation with his origin obsel(s) from the trace of level *n-1*. The obsels of

[1] http://liris.cnrs.fr/silex

the Primary M-Trace are in relation with the data collected by the simulator. Such structure allows instructors to explore, analyze the trainees' activities with a top-down investigation to understand the reasons, be they individual or collective, of failure. Consequently, instructors would also be able to better prepare and conduct the session's debriefing with trainees. On the other hand it would be possible to help young Instructors to improve their skills by helping them in observing Trainees. For example, if the trainers wants to understand the reasons why the obsel "Professional Gesture " of the M-Trace of Pedagogical Objectives Family is KO[2] (see figure 2), he has just to navigate through their different origin obsels of the Intermediate M-Trace. In this case we find: "Adjustment of the alternator voltage", "Use of the good instruction", "Regulation of temperature" and "Coupling". According to the Rule 9, the obsel "Professional Gesture" is OK only if all of these four origin obsels are OK. In our example, as far as one of these obsel is KO, "Regulation of temperature", the obsel "Professional Gesture" is KO too. On the same principle, the trainer can explore the obsel of the Primary M-Trace in order to understand the reasons of failure for the obsel "Regulation of temperature".

## V. TRACE AND TRANSFORMATIONS MODEL.

We detail in this section our trace and transformation models we have proposed to meet our objective to help observation process and the analysis of trainees' activities in NPP Full scope simulator.

These models are illustrated by examples from our project with UFPI. For confidentiality reasons, we do not present all the information related to these models.

### *A. Trace Model*

Whatever the level of M-Trace, its model and the simulator used, we believe that a simulation M-Trace must "pick-up" its own identity to be locatable and usable over time. This "identity card" of the M-Trace would be particularly useful for large-scale statistical research and/or analysis on a set of M-Trace corpus, and particularly to feed Experience Feedback, described in the Trace-Based framework presented in [1]. Through Experience Feedback, trainers try to understand good or bad practises in order to improve contents of the future training courses at a national level.

So, as described in the class diagram of figure 3, all the M-Trace of our model has an ID, a beginning and end date, the level of M-Trace (Primary, Intermediate, Pedagogical objectives family), type of simulator (EPR, CP0, N4), type of training (Initial Training or Retraining), category (Summative, Formative), with the scenario of simulation: (islanding, Evolution in monophasic of the primary circuit, or Evolution in diphasic of the primary circuit, etc.), training program (Op Reactor, Op Turbine, Supervisor, Manager, etc.).

[2] This means that the operator did not validate this objective

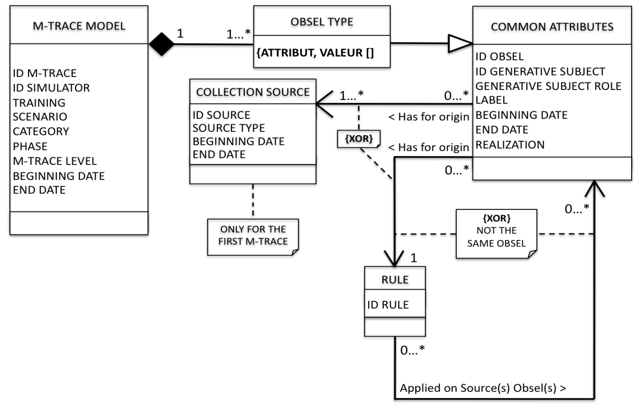

Figure 3. Trace Model

Each M-Trace is composed of a set of observed elements ("obsel") that has a type, a label and a time stamp in the M-Trace. The obsels we collect are the result of interactions between users (trainees and trainers) with the FSS, and the simulation of the NPP simulation process itself. We have identified several obsels types. Each obsel type has an ID, a begin and an end date, a label, the ID of the Generative subject (ID of the Person, of the Group of persons or of the Simulator), the nature of the subject (Evaluated or not), the role of the subject (Op Reactor, Supervisor, Manager, etc.) and the realization attribute (OK or KO). We can also add specific attribute related to the traced action. For example, the attributes of the obsel *alarm* are: elementary sub system, order number, etc.

In order to guarantee the exploration between various levels of Trace, each obsel possess a link on its origin. The origin of an obsel type can be a collection source (video, sound, logs…) if it's the primary M-Trace, or directly a rule of a transformation for the other case.

### *B. Transformation Model*

Let us call back that transformations allow generating a target trace of level *n* from a source trace of level *n-1*. Each Transformation is based on the same model: it's composed of a set of rules which have a part « Condition » and a part « Construction » (Figure 4).

The *condition part* expresses constraints on the elements (obsel type, relationship type, values of attribute, etc.) of the M-Trace(s) source(s).

The *construction part* allows defining the obsel and the relationships of the new target M-Trace (higher-level) if all the constraints of the condition part are satisfied.

For each part of a rule (condition and construction), it's also possible to use specific operators as arithmetic, Boolean and / or comparison in order to:

- stronger constraint attributes values of the condition part or
- make calculation on the attributes values of the obsels in order to initialize (construction part).

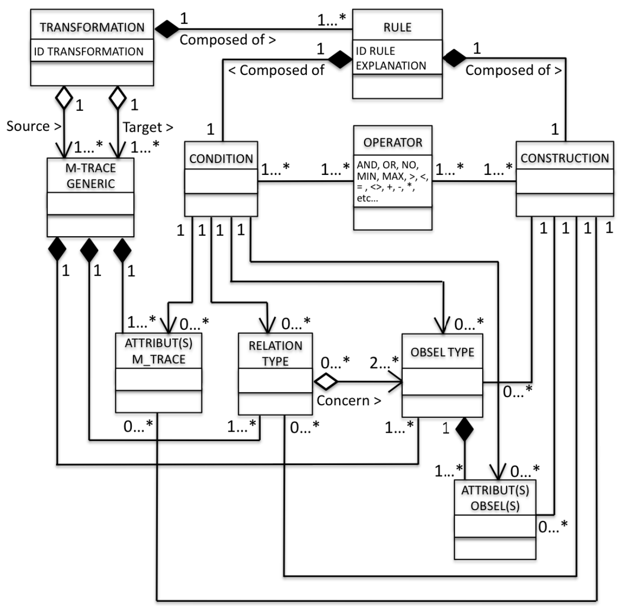


Figure 4. Transformation Model

In the following section we present the prototype D3KODE.

## VI. D3KODE.

D3KODE as « Define, Discover, and Disseminate Knowledge from Observation to Develop Expertise » is a Web application based on N-Tiers architecture. This application allows storing and transforming traces according to the organization and the models presented in previous sections. D3KODE also allows the user to interactively view the various trace levels. So the trainer can explore the different abstraction level in purposes of investigation and / or education to target gaps and difficulties of each trainee.

The application server of D3KODE is Apache TOMCAT and the framework Struts2 is used for the presentation and visualization of M-trace levels. The storage of M-Trace (Model and Data) and dedicated transformation model and rules is based on the kTBS (kernel for Trace Base System). The kTBS [3] is a Trace-Based Management System architecture [2] developed by the SILEX team. Data of the kTBS are encoded in RDF [4] (Resource Description Framework). The transformation rules, for abstracting the M-Traces, are written in SPARQL1.1[5].

D3KODE is thought to be multi-user and multi-language. Actually the languages are English and French.

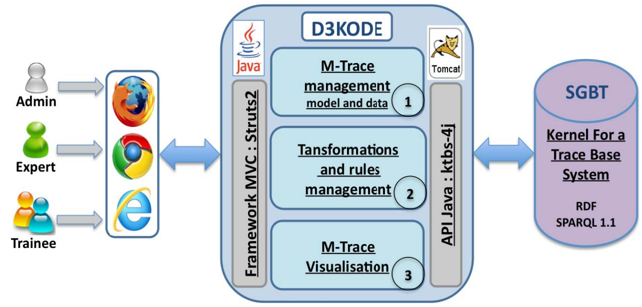


Figure 5. Architecture of D3KODE

In the following sub sections, we describe the different steps to use D3KODE, that is: configuration of knowledge, input data, execution of transformation rules and visualization of M-Trace.

### A. *Configuration of D3KODE*

D3KODE allows the creation, modification, remove and consultation of trace model and transformation rules.

Throught a specific WYSIWYG HCI, expert users and trainers, have the possibility to create a M-Trace Model, manipulate the obsels types, relation and associated attribute. About the transformations the HCI of D3KODE give the possibility to specify, for each rule, the criteria of the part “condition” to be matched and, in the part “construction”, the obsel type that will be created if the part “condition’ is respected (see the figure 6). Once D3KODE is configured, it can be used for all the training simulation session that correspond to the trace and transformation model.

### B. *Input data*

After each simulation session, the trainer recovery all the simulation data from the collection sources as logs, videos, calculation notes of trainees, etc., Then he/she format them according to a specific protocol in a CSV file. This pre-processing is necessary to make D3KODE encode data. Afterwards, the CSV file is loaded in D3KODE through a HCI. From the data of this file, D3KODE generate a first M-Trace, called Primary M-Trace, which can be visualize and transformed.


Figure 6. D3KODE – Rule creation HCI

[3] http://liris.cnrs.fr/sbt-dev/ktbs/

[4] http://www.w3.org/RDF/

[5] http://www.w3.org/TR/sparql11-query/

### C. Execution of the transformations

In order to analyze the trainees's activities and prepare the debriefing, trainer must execute the transformation rules to create higher M-Trace levels from the primary M-Trace. For this, D3KODE browses all the transformation rules, introduce during the configuration step, so as to find rules whose condition part matches with the obsels of the primary M-Trace. These rules are executed to generate the obsels of the intermediate M-Trace. The same mechanism is applied to generate the M-Trace of Pedagogical Objectives Family from the intermediate M-Trace.

### D. Visualization of M-Trace

The visualization part in D3KODE allows trainers to explore the different M-Trace levels. This exploration can be done in two dimensions: horizontal and vertical. In the horizontal dimension, the obsel of the M-Trace are displayed with respect to their occurrence in time. For each of this obsel, the trainer can display, every time, value of the attribute. The vertical dimension shows the relationships between each observed and observed its origins. This dimension allows trainers to understand the reasons for success (if the observed high levels are OK) or failure (if the observed high level are KO) trainees.

## VII. Evaluation Protocol

The objective of the evaluation is to determine if D3KODE facilitates the work of trainers in the observation and analysis of operators' activities trainees from the analysis of their traces. For that, we, as a first step, create models of traces and transformations rules. Next, we have defined an evaluation protocol based on a comparative method. This is to compare the analysis of the activities of students with and without D3KODE to determine if the different concepts on which it is based facilitates the work of trainers. This evaluation is conducted with a team of experts, trainers and trainees from UFPI, and is applied to an islanding simulation scenario of a Nuclear Power Plant. This scenario is called *islanding scenario*.

In this section, we describe in a first time the islanding scenario before presenting an overview of the two phases of our evaluation process.

### A. Simulation scenario: Islanding

According to UFPI, an islanding scenario is defined as following *"Islanding is an operation to protect NPP against failures on the electricity network (unballasting). It consists in isolating the plant of the electricity network, while maintaining a power minimum to guarantee a functioning in automatic of the regulations. The reactor produces then (through its alternator) only the electrical energy to feed his own auxiliaries (Pumps, regulations, etc.). In that case, we speak about success islanding. In case of failure, the protections of the reactor allow to bring this last one in a state of fold, so guaranteeing the control of the security and the plant.*

*The objective of the operators is to apply a specific procedure to master the management of this "complex" transitory, the evacuation of the residual power of the reactor being safely made through appropriate circuits. The islanding scheme is maintained until the situation returns to normal network. Upon the end of the network outage, the plant can be recoupled. This islanding operation is particularly subject to periodic testing to verify proper operation of systems and automatic regulation."*

During the simulation each trainee has to realize specifics actions, which will be translated into obsels to be checked by the trainers with the help of D3KODE.

### B. Creation of trace model and transformation using the Template

Remember that the principle of our approach of observation and analysis of operators' activities is to organize the simulation data into three levels of m-traces, where each level n is created from the observed transformations of the trace level n-1.

In order to create Traces models and dedicated transformation rules, we have organized a reference simulation to obtain data without mistakes. The simulation was conducted by an expert trainer on a NPP FSS of the EDF Group during 1 hour. At the end of this first step, we have asked another expert to analyze the simulation collected data and the observation balance sheet performed by the previous trainer. During this step the expert was filmed and invited to use "think-aloud protocol" to help us analyze his action *a posteriori* by confronting him with the video recording of his own activity [4]. We have then analyzed two hours of video. Such analyze allows use to create, from a Primary M-Trace of 4609 obsels, 7 different obsel types. The Intermediate M-Trace model contains 24 obsels type: 18 obsels for the OP Reactor, 5 for the OP Turbine and 2 potential deviations. The Pedagogical Objectives Family M-Trace model is composed of 3 obsels type: 3 obsels for each operator. Concerning the transformations, we have created sixty rules: 48 rules between the Primary M-Trace and the intermediate M-Trace and 12 rules between the intermediate M-Trace and the M-Trace of Pedagogical Objectives Family.

### C. Evaluation protocol

Once the expert validated all the M-Trace models and transformation, we have injected them into D3KODE. The second step of our evaluation method is to determine if D3KODE facilitates the work of trainers in the observation and analysis of operators' activities trainees from the analysis of their traces. For this, we have defined an evaluation protocol based on a comparative method. The principle is to compare, by an expert, the results of analysis and debriefing of two simulation sessions, the first without D3KODE and the second with D3KODE.

As explain in the figure 7, the first simulation session is conducted by a trainer, called A, with 2 trainees, operators A and B. At the end of the session, the trainer prepare the debriefing with a traditional method: his own notes, the balance sheet of the simulation, videos of trainees, etc.

The second simulation session is conducted by the same trainer, called A, but with two new trainees operators, called C and D. We specify that A and B have the same skill level as C and D. In order to prepare the debriefing, the trainer use

D3KODE to analyze trainees' activity. For this an analyst, recover the simulation data and inject them into D3KODE. This action will allow the trainer to execute transformation rules (previously introduced into D3KODE) on the Primary M-Trace from the simulation data.

An expert attends the debriefing of the two sessions to compare and analyze the results of both simulations. The assessment protocol is being implemented.

## VIII. CONCLUSIONS AND PERSPECTIVES

This article addresses the problem of observing and analyzing behavior of students on full-scope simulator. This work, conducted in partnership with the UFPI EDF, is applied in the context of training and maintaining competence control operators of nuclear power plants. The objective of our work is to propose models and tools to help trainers observe and analyze trainees' activities. Specifically, It consists in supporting the trainer in the preparation phase of debriefing. The approach we proposed is to transform the raw traces, based on data collected by the simulator, in order to extract high level information on the activities of trainees. For this we have proposed trace model and dedicated transformation. Thus, the proposed models allow you to keep a link between the observed target (level n) and the observed sources (level n-1).

We have also developed a prototype, called, D3KODE that can store, process and visualize traces. This prototype implements the various models we have created. So as to validate our approach and applicatives contributions, we have proposed an evaluation protocol based on a comparative method. This evaluation protocol is conducted with a team of experts, trainers and trainees from UFPI of EDF Group.

The second step of this protocol is in progress.

Our Future work will aim to address the second objective of the project: exploitation of traces for the experience feedback to refine the needs and optimize training programs for years to come.

## ACKNOWLEDGMENT

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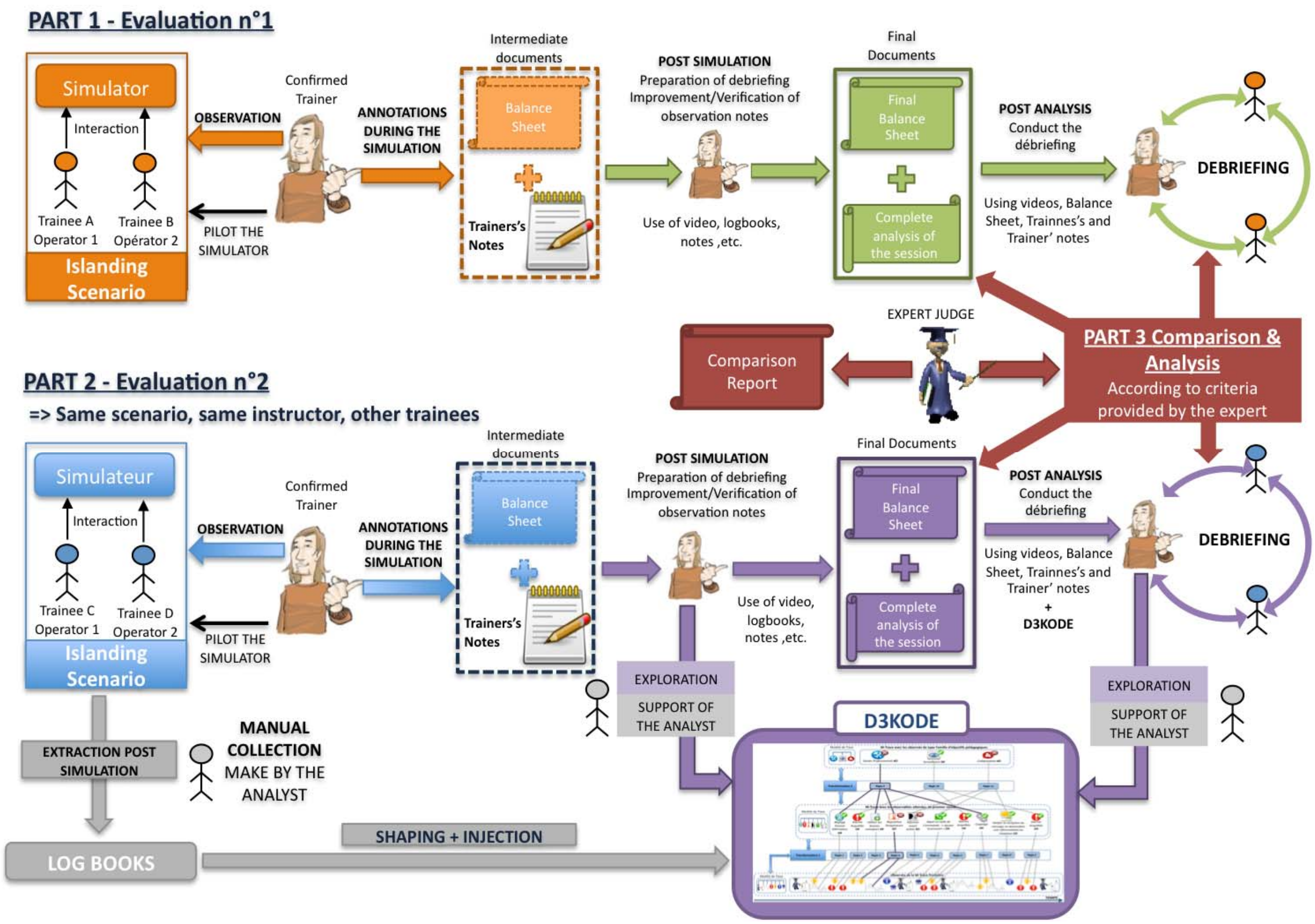


Figure 7. Description of the evaluation protocol