The use of computer simulations in specific job training, risk communication and safety

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Abstract
A general training of the work force in radiation protection forms the bases of a good attitude towards the risks involved in working with radiation sources. However some problems or tasks can be very specific and demand detailed information about the work site and the radiation risks involved. This presentation shows how 3D simulation, virtual reality technology and internet technology can be used to support specific training and communication in the radiation protection field. Research on this subject and a working tool are presented.
A part of the training on the work floor can now be replaced by training using computer simulation techniques thus avoiding exposure during job training.
The capabilities of the software tools allow the visualization of the radiation risk in dose rate maps and dose rate value displays at the worker position.
Simulation tools allow the evaluation of work scenarios, scored on their dose account, supporting decisions in the ALARA analysis.
Using these techniques allows a better training of the workforce through a better understanding of the workplace and the radiation risks in involved.

1. Introduction
Human operations are required in nuclear installation, during maintenance, outage, repair and decommissioning. This leads to the exposure of the worker to radiation and it is clear that these operations must be performed according to the ALARA principle (to reduce the dose as low as reasonably achievable) [1]. The person responsible for planning the job needs to evaluate different scenarios based on the exposure of the worker. This involves the manipulation of a lot of information specific to the work place such as the geometry, materials, radiological and technical boundary conditions. The analysis of this information and its influence on the occupational exposure leads to the selection of an optimum scenario defining the work plan.
The work plan then needs to be presented to the worker in order to prepare him for the tasks demanded on the work floor. Confronted with a new work description he will require an information session or a pre-job training. The job specific training provides the information for the job at hand, the associated risks, the protective means deployed and the description of the residual risk remaining. This will prepare the operator to perform the work in an efficient and risk informed way.
The planning and the communication of the work scenario in the traditional way, based on documents and plans can be very cumbersome and tedious as a lot of information on geometry, materials, sources, dose distributions and work techniques are involved. Simulations provide an excellent means to make the above mentioned process more efficient and effective by visualizing the environment and the associated risk.
In recent years the possibilities of simulations in a 3D environment have increased rapidly, different firms and research institutes have or are exploring this route leading to a number of applications. We mention here only a few of the developments such as VR-Domain from Rolls Royce Associates [2], Virtual Radiation Fields from the University of Florida [3], VR-dose by Halden VR-centre [4], Internet VR for KODADA-1 [5], Visualization of radiation fields by Hitachi Ltd. [6], ErgoDose (NNC) [7-8] and HesPi of the polytechnical university of Madrid [7-8] and the VISIPLAN 3D ALARA planning tool of SCK•CEN [9-10].
A difference can be made between the on-line simulation tools and planning tools.
The on-line simulation tools concentrate on the detailed actions of the operator in practically real time, simulating the movement continuously through the 3D environment and the dose rate field. Planning tools concentrate on the evaluation of the dose rates at the different working positions and calculate the dose for the different scenarios. The planning tools are directed to a global dose evaluation of the work scenarios. The advantage of the on-line tools is that they can be used in detailed operator training with a continuous dose display on the screen. The movements of the human 3D

representation are very detailed and realistic showing even the manipulation of different objects in the scene. A disadvantage however is the time necessary to perform these detailed simulations although interesting for training but not very productive for job planning activities and optimization. It is our feeling that the on-line simulation tools are best used for training of difficult tasks requiring very detailed operations by the worker. In practice these tasks do not occur frequently. For the other tasks a simulation showing the general position of the worker is sufficient. For an ALARA evaluation of an operation involving different trajectories in different 3D geometries a planning tool is better suited because it allows you to quickly asses the dose for different work scenarios without going into the sometimes time consuming detailed human movement simulation in the environment. It is in this context that we developed the VISIPLAN 3D ALARA planning tool. In this paper we further concentrate on this tool and its applications. We also highlight some results of the VRIMOR project an EC 5th framework project, in which we participated, on Virtual Reality in Maintenance operation and repair.

2. The VISIPLAN tool

Confronted with the decommissioning of the BR3 reactor and the need to perform ALARA evaluations of the work SCK•CEN started in 1995 with the development of VISIPLAN 3D ALARA planning tool [9-10]. It was first developed as a calculation tool that allowed the ALARA analyst to perform pre-job studies in order to optimize the radiation protection. The method used for the dose assessment is based on a point-kernel calculation with an infinite media build-up correction. The tool calculates the dose account for different work scenarios defined by the ALARA analyst, taking into account worker position, work duration and subsequent geometry and source distribution changes in a 3D computer simulation of the work place.

The VISIPLAN methodology is based on four major steps, model building, general analysis, detailed analysis and follow-up.

In the first step the computer model of the environment is build based on the known geometry, the materials information and information about the radioactive sources of the site. This results in the basic geometry from which other geometry's, mostly with supplementary shielding, can be derived. When the sources are known a calculation of the radiation field can be performed immediately. The model can be build by introducing a set of primitive volumes (box, sphere, tube ...) or can be read via an interface called VISIMODELLER from the CAD software Microstation [11]. This interface was established between VISIPLAN and the Microstation CAD package through collaboration between Tractebel Engineering and SCK•CEN. This interface enables the transfer of the geometric data of the CAD system to the VISIPLAN system reducing the time spent in the geometric building process of the environment.

In the general analysis phase the calculated dose rate fields are studied and suggestions about shielding or dose reducing techniques are tested and analyzed again using calculated dose maps. Once a dose reducing technique is chosen a detailed dose calculation is performed along a trajectory consisting of a series of tasks, characterized by a position, a task description and work duration. Scenario's can then be build through a selection of trajectories calculated in the different geometry's. Collective and maximum individual dose are used to compare the different scenarios and select the most optimal one.

In the follow-up stage the dose accounts of the workers are compared with the predictions from the model. When large deviations occur, a reassessment of the work is performed by adapting the model to the new information. This makes it possible to adjust, and thus to further optimize the work procedure during its progress.

The VISIPLAN tool has been applied to many dose optimization problems at the SCK•CEN and other nuclear installations [12-14]. Recently we performed a simulation of the procedure to load a spent fuel bundle in the zero power critical facility VENUS of the SCK•CEN. In this procedure we were confronted with a lifting operation that restricted the mass of the spent fuel shielding [16]. With the simulation (figure 1) we were able to show that the amount of shielding that was allowed was sufficient to keep the dose reasonable taken into account the total duration of the operation. The simulation of the dose rate field near the spent fuel container was used to inform the workers allowing them to position themselves in a lower dose rate field during the lifting operation.

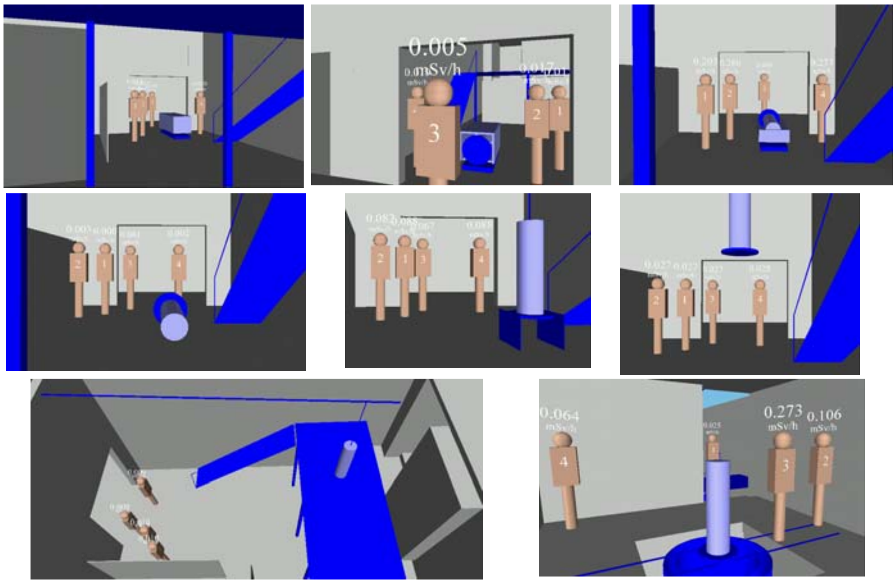

Fig. 1. Simulation of the spent fuel loading operation using VISIPLAN 3D ALARA planning tool.

Currently we are examining the dismantling of the high level liquid waste tanks of the Belgian Reactor 3 (BR3). One of the preparatory operations is the cleaning of the tanks with a high pressure cleaner. The sequence of the operation is represented in figure 2. The figure is a direct result of the VISIPLAN simulation and can be used to inform and prepare the workers.

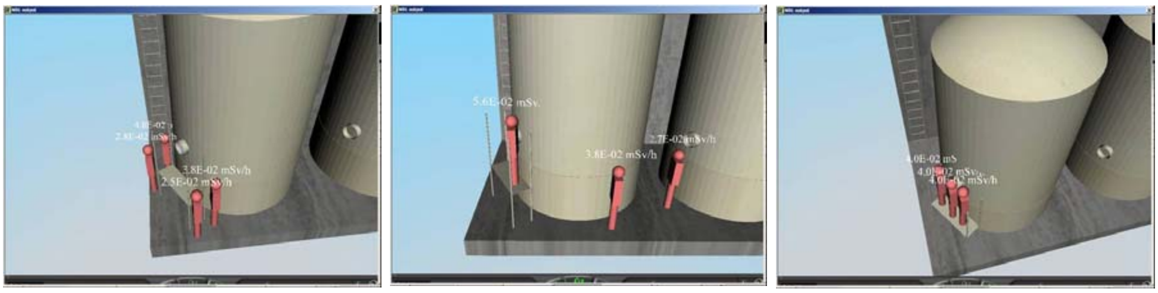

Fig. 2. Simulation of the cleaning of the high level waste tanks at BR3 (from left to right the placement of the scaffolding, the placement of the high pressure cleaner and the cleaning operation with a gradually reducing source strength).

3. VISIPLAN as a training and communication tool

Soon it was discovered that the tool besides being a calculation tool, also contributed to the communication between the stakeholders in the ALARA process such as the planners, the radiation protection people and the workers. It also served as a training tool in order to introduce the ALARA philosophy to the planners, who were now able to assess the dose for different work approaches in pre-job studies.

The availability of a 3D representation of the workplace, the trajectories and the dose assessment also helps in the group decision process in the ALARA concept. The different stakeholders are confronted with the same data presented in a user friendly format allowing more efficient discussions and the introduction of possible new alternative work plans.

Special tools are provided in order to make the 3D environment and the results of the simulation available to the stakeholders. These tools are a VRML-converter and a web-generator. The converter creates a VRML output file containing the information about the 3D model and the simulated trajectories. The VRML file has a compact format allowing an easy distribution on inter- and intranet. The web-generator creates, from the results obtained with VISIPLAN, a web site containing the information of the different simulated scenarios with their respective dose accounts, VRML models of the geometries and trajectories including dose information. The creation of this web-site allows the stakeholders to view the results in 3D without having to make use of the basic calculation tool.

These tools are used for individual viewing and verification of the information but are also used for viewing and discussion during face-to-face meetings and are a support during worker training or information sessions.

4. Human motion simulation tools

SCK•CEN collaborated with the VISIPLAN 3D ALARA planning tool and the experience gained with it in the European 5th framework program called VRIMOR standing for "Virtual Reality for Inspection, Maintenance, Operation and Repair". The aim of the project was to show the viability of an integrated approach to minimize occupational exposure through the combination of different technologies including gamma scanning, geometrical scanning, human motion simulation tools and a radio-geometrical modelling tool [7]. During the project we established a set of interfaces enabling the data transfer to and from the different tools involved in the project. This technology has been applied at the Almaraz Nuclear Power Plant in Spain and resulted in a Technological and User Perspective Review Report by Tecnatom Spain [8]. The interfaces developed involve the human motion data obtained by the human modelling tools ErgoDose developed by NNC Ltd UK and HesPi by Universidad Politecnica de Madrid, Spain. The radiological characterization makes use of the gamma scanning interface to import and analyse gamma scans measured with the EDR gamma scanner from CIEMAT [17-18]. A third interface was established between the Light Form Modeller tool from Z+F Ltd UK enabling the transfer of a scanned geometrical environment to VISIPLAN.
The availability of these data exchange interfaces between the different tools of the partners allows an integrated approach to ALARA in maintenance outage and repair in existing Nuclear Power Plants going form characterizing the work area to the work simulation, dose assessment and dose optimization.
The ErgoDose and the HesPi human motion simulation tools allowed a detailed description of the human movement resulting in detailed trajectories of hands, chest and head. ErgoDose made use of a SpaceMouse driven interface to generate the avatar movement while HesPi was based on a voice driven interface.
The evaluation of the dose for a task simulated by VISIPLAN (static avatar), ErgoDose and HesPi (dynamic avatar) showed that the detailed description of the movement of the avatar did not lead to major differences in the dose account of the worker. The differences are in most cases smaller then the uncertainty on the time of the simulated operation. Although in most cases not so important for dose planning, the detail of the movement is an added value in the communication of the task content to the operators.

5. Conclusion

The use of computer simulations in specific job training, risk communication and safety has several advantages. The information is presented in a straightforward way using 3D graphics representing not only the environment but also the radiation conditions of the work area. Regarding the level of detail needed in the simulations we must strike a balance between the very detailed and the more static human motion simulations. It is our view that a restricted set of human postures is in most cases sufficient and adequate for both simulation and communication purposes. The use of a restricted set of postures avoids over detailed and time consuming simulations but provides enough information on the position of the worker in the environment. This will lead to a tool that is efficient both in planning and in communication.

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