PURPOSE AND BENEFIT OF CONTROL SYSTEM TRAINING FOR OPERATORS

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Abstract

The complexity of accelerators is ever increasing and today it is typical that a large number of feedback loops are implemented, based on sophisticated models which describe the underlying physics. Despite this increased complexity the machine operators must still effectively monitor and supervise the desired behavior of the accelerator. This is not alone sufficient; additionally, the correct operation of the control system must also be verified. This is not always easy since the structure, design, and performance of the control system is usually not visualized and is often hidden to the operator. To better deal with this situation operators need some knowledge of the control system in order to react properly in the case of problems. In this paper we will present the approach of the Paul Scherrer Institute (PSI) for operator control system training and discuss its benefits.

INTRODUCTION

For the scope of this paper a machine operator is someone who monitors and supervises the behavior of one or more accelerators from a control room. Typically, the only connection between the operator and the physical machine (which can be hundreds of meters away) is the control system with the computer network it is implemented on. In the case of PSI the operators are responsible for four different accelerators each with its own control systems, most of them based on EPICS.

The general task of the operators is to remotely control the accelerators. During normal machine operation this narrows down to setting up and optimizing the accelerator settings according to the scientific needs on one hand and handling system misbehavior and faults on the other hand.

As there is no other connection between the operator and the accelerator all this has to be done through the control system, or more precisely through the user interfaces of the control system.

MENTAL MODELS

In a perfect world the control system is transparent to the operator. The operator would only need to know about the accelerator. All relevant information would be provided by the control system, correctly and in the right way. Unfortunately, there is no perfect world. Even the "right way" to display data is different from one user to the next and from one use case to the next.

If the control system can not represent the accelerator correctly, it is not transparent to the operator. This implies that information is changed on its way from the accelerator through the control system to the operator. The data is distorted by the control system like a picture is distorted by a colored lens. Therefore, the operator needs some knowledge about the control system and how it works in order to be able to recognize the distortion and clean up the information.

In cognitive science and psychology the internal human representation of a complex external system is called a "mental model" [1]. We develop such models to help us handle the complexity of the real world. They assist us in simulating alternative behavior before applying it. And in addition, they allow reasoning about the way the systems will behave or develop [2].

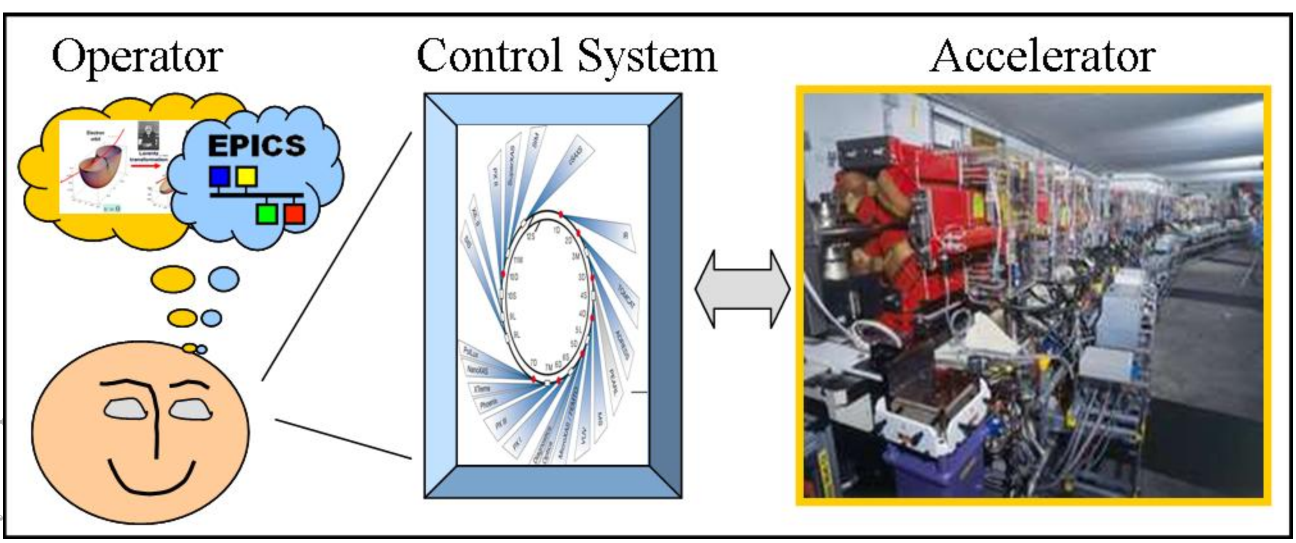

Figure 1: Operator relationship to Accelerator and Control System.

Unfortunately, to make a mental model work and fit into the “working memory” of a human brain, it has to be simplified. The aspects that are represented are influenced by background knowledge and developed over time with experience.

In the context of accelerator control the operator has to maintain two mental models: one for the accelerator and another for the control system of that particular accelerator. As the main task of the operator involves operating accelerators the mental model of the accelerator is usually acknowledged by everyone. For the majority of operator tasks this might be sufficient but as soon as some unusual situations appear the mental model of the control system gets more important. Especially during error diagnosis and recovery it is vital for the operator to distinguish between errors in the accelerator and errors in the control system.

CONTROL SYSTEM TRAINING

The question is how to influence the mental model operators have about the control system in such a way that it represents the actual reality. Fortunately, mental models are not static but change over time through learning and experience [3]. This led us to a twofold approach for operator training for the Swiss Light Source (SLS) at PSI.

EPICS Training Course

The first step prepares the ground and provides the theoretical background information. This is done in the “EPICS Training at PSI” course [4]. It consists of a lecture part and afterwards hands-on training. The lecture concentrates on an overview of the control system and informs about technical terms and general ideas.

We found that it is important to provide this lecture in German, the native language of the operators at PSI. Presenting unfamiliar concepts in a foreign language makes it more difficult to learn and accept these concepts. For scientists who do not speak German fluently the same course is available in English as it is not feasible to provide it in the native language for everyone.

Directly after the lecture a hands-on training is provided. Each operator has a dedicated control system console available as well as some hardware connected to a server. They are tutored to configure the server so that they can remotely control the hardware from the console. Some exercises are provided in order to channel the training but there are no constraints to what the operators can do.

It has been proven crucial for the success of the training to provide a safe playground and make the operators aware of it. Otherwise the fear of doing something wrong or making a mistake hobbles the playful approach. Without pressure the operators can find out how the control system reacts to faults and discover what to do in fault situations in their own speed of learning.

As the speed of learning can vary a lot given the diverse backgrounds of course participants, it is important for the trainer to have small groups. The PSI EPICS Training is provided once per month but only for four people at a time. This ensures that the trainer can concentrate on each student. In addition, each student having his own computer and hardware does not allow hiding behind someone who knows more or is quicker to understand.

Training through Experience

As mental models change over time they can decay. This happens if the knowledge of the operator is no longer up to date due to changes in the system, or if knowledge simply gets forgotten. In addition the build up of a mental model is quite slow for new operators if there is no possibility to gain experience.

In this aspect the excellent availability of the SLS has proven to be a problem. Faults occur too seldom to keep the mental models up to date. Because of this, mental models of operators (both, the accelerator model as well as the control system model) are subject to decay. But as the accelerator model gets some stimulation from change of setups and optimization of the facility it is less affected.

To counteract this knowledge decay we have introduced the “SLS Operator Training”: once per month during scheduled machine time the trainer creates a problem with the actual accelerator facility. The problem is created by a dedicated program called “sabotage” that randomly selects one of several possible error sources and applies it to the accelerator or control system. One operator is chosen to solve the problem while the other operators and the trainer watch and provide help if needed.

In addition to providing experience in fault handling, the operator training allows to reflect on the way problems appear through the filter of the control system. Even if the induced fault is not connected to the control system the operator gets practical knowledge on how the control system shows problems and where to look for indications of misbehaviour.

The operators that observe these problem solving sessions have the possibility to compare the approach of their colleague to their own approach.

WHAT ELSE CAN BE DONE

To support mental models about the control system the functionality and status of the system itself should be visualized. Such user interfaces allow the operator to supervise the control system more explicitly than only through the behaviour of accelerator parameters.

Examples could be the status of network connections or hardware servers (called IOCs in EPICS). The EPICS framework provides already some tools for this purpose: the connection status of each parameter is available to the client automatically (but still needs to be displayed) and the vxStats package evaluates the status of an IOC. But error messages and status information of control system internals are often obscure. To avoid confusion, explanations or a glossary has to be displayed as well.

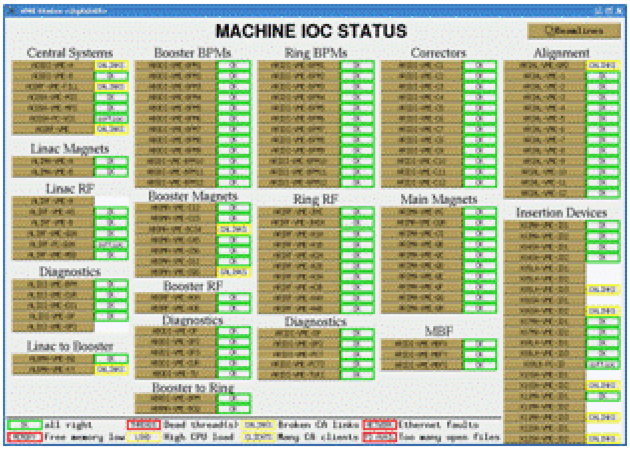

Figure 2: Example of a status screen for visualisation of Control System functionality.

Including control system information in error messaging systems like the EPICS "alarmhandler" can help the operators to distinguish between accelerator errors and control system errors. But it can hide the difference as well. Therefore, the implementation has to be thought through carefully.

CONCLUSION

Operators need mental models of the control system to recognize fault states and react appropriate to errors and misbehavior of both, the accelerator and the control system itself. Mental models gained only on infrequent experience can be imprecise or plain wrong in worst case. Control system training can provide a foundation to build better mental models and therefore help to enhance operator responses and machine availability.

For a refinement of the mental model repeated experience is needed. This can be provided by trainings sessions at the real accelerator. Reflection and discussion of the monitored error handling approach can optimize the impact.

ACKNOWLEDGEMENTS

We would like to thank

- Detlef Vermeulen and Anton Mezger for their support of the different trainings.
- The whole Controls Section for help and feedback.
- The PSI Operators for their patience.

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