How should causal knowledge about complex technical systems be trained?

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Abstract

A theoretical approach is presented for the support of causal knowledge acquisition in interaction with complex technical systems through training. De Kleer and Brown's theory of mechanistic mental models serves as the basis for a framework for both causal knowledge acquisition and application. Issues for operator training in complex systems are deduced. Three training modules are presented that attempt to impart knowledge about how the system works at different levels of system simulation and interaction. A pilot study explored a first operationalisation of the training modules and the applicability of a selected microworld for the investigation of causal model acquisition. Results showed that training according to the framework leads to appropriate causal knowledge acquisition. Results further revealed that the simulation in use is not complex enough. Future work will address more complex simulation environments and the operationalisation and implementation of all three training modules.

Introduction

Operators in safety critical systems rely on their internal representations of the causal functioning of the system when performing process control tasks. These causal models can be understood as a special form of mental models (Thüring, 1991; Einhorn & Hogarth, 1986) that describe knowledge about causes and effects. They enable operators to perform various tasks such as prediction of future system states, search for system abnormalities and breakdowns, and select appropriate system interventions (Hollnagel, 1998). Thus operator training strategies have to consider theories about causal knowledge acquisition. Various theories describe how users develop mental models during interaction with complex systems (e.g. Rasmussen, 1979; Moray, 1996). An approach to describe how causal models of technical devices are acquired is presented by de Kleer and Brown (1983). They identify four relevant aspects for the development of a causal model. The first aspect is the device topology (1), which is basically the representation of the components and the structure of a given device. Device topology forms the input for a qualitative simulation process, the envisioning (2). To determine the overall functioning of the device, every single component has to be represented, and associated components have to be connected. The output of this deduction process is the causal model (3). It

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