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Performance Support Systems and Artificial Intelligent Considerations

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Summary

Recent focus on intelligent performance support systems for reactor operators has resulted in several major reviews. Among top desirable features for these operator destined computer-based systems are human-centred design, intelligent behaviour and real-time performance. The philosophical approach of human-centred design, so necessary for the operator to be in control, is outlined and extended to include the concept of user mental models. Other fields apply artificial intelligent (AI) techniques to offer such approaches and operator companions for the nuclear industry seem also to be similarly amenable. Intelligent behaviour is extremely germane to these systems and includes two domains: (1)what information is to be conveyed to the operator under any given situation and (2)how that information can be optimally presented to the user to maximize data transfer and minimize the time required via the man-machine interface. AI can aid in the realization of these goals; however, such techniques are resource intensive and not easily adapted for real-time applications. The fundamental design principles of temporal and functional abstractions have given other knowledge-based control systems adequate response times for nuclear particle accelerators which are simpler systems but results seem promising for more complex problems. Other AI applications which appear fruitful to examine include intelligent and context sensitive help procedures (expert systems excel at explanatory applications) and the use of on-line and parallel AI paradigms for system validation to aid in licensing issues. Most of the above features are being either explored or implemented in an anthropomorphically designed, agent oriented approach and distributed architecture-based multi-computer system called the OPUS (OPerator / User Support) System. The overall approach is detailed and the impact of the methods to the field is considered.

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Introduction

Operating plants, such as nuclear -electric generating stations and chemical process plants are typically large and complex, incorporating many remote and indirect sensors. Today's operator of such facililties function in a data and information rich environment. It is generally conceded that mechanisms are badly needed to help the operator assess and assimilate this information to assist in the daily decision-making process.

Recent focus on intelligent performance support systems (PSS) for reactor operators has resulted in several major reviews[1,2]. Among top desirable features for these operator destined computer-based systems are human-centred design, intelligent behaviour and real-time performance. PSS can derive their origins from the realization that intelligent open loop complex plant control actually involves consideration of the human component as well as the more traditional machine (or process) part of the system. Also for the PSS to be effective, real-time capability in the time frame of the process to be operated is necessary. It is in this milieu then, that the role of Artificial Intelligent (AI) techniques can play in PSS operation is examined.

User Centred Approach

The term PSS is considered, for the case at hand, as any system which aids the plant process operator and is sensitive to the status of the plant process[3]. This work serves to amplify the above concepts with special emphasis on nuclear power plant operations. This will later be extended to include process environmental awareness as well. That is, early process control systems exhibited machine -centred characteristics, and then advanced to the human-centred capability. There is yet another possible level of interaction and this is a user-centred approach. Here, AI can play a significant role in such a system. Figure 1 shows the historical development leading up to the PSS, where the promise is to bring the complete integration of knowledge into a contextual environment in which the operator always functions. Hence the PSS, to optimize its utility to the operator, must be capable of functioning with the operator via a series of levels of interactions. That is why the next stage beyond the human-centred approach has been termed the "user-centred approach".

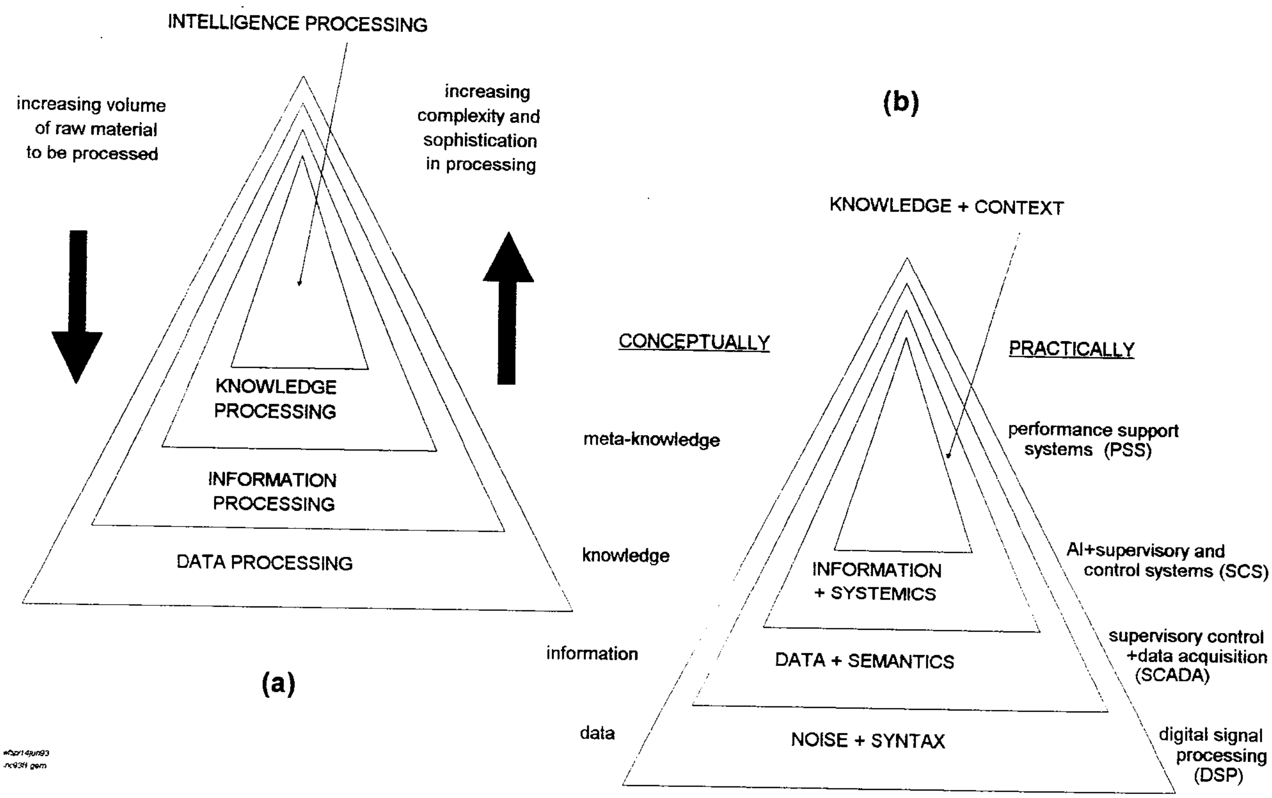

Figure 1:(a)computer processing;(b)mapping to process space.

To examine such a possibility, consider figure 2 which has been adapted from Garland, 1993[4]. Although this referenced work and others are more concerned with the question of the distinction between the process design engineer and the process operator[5], the nature of human problem solving model [6] is ideal for the purposes at hand.

Note from the figure that the operator, largely without computer assistance, can function with skill-based reasoning at the operational level. When necessary, usually at time of process upset, the operator must apply some rule-based knowledge to function at an enhanced or tactical level. This is commonly referred to as human-centred activity where a computer is involved and supplies pertinent information as directed. (Eg., on-line procedure access [7], alarm pattern analysis[8]etc.). However, in the user-centred approach, the PSS is always tracking the plant process and based on queries or responses given to it by the operator, is cognizant of the human operator probable requirements. For instance, constant computer monitoring of the reactor regulating system of a CANDU plant can identify abnormal cycling, suspect signals, controller errors and flux tilts within the context of a refuelling operation and provide the Chief Reactor Operator (CRO) with performance data before or

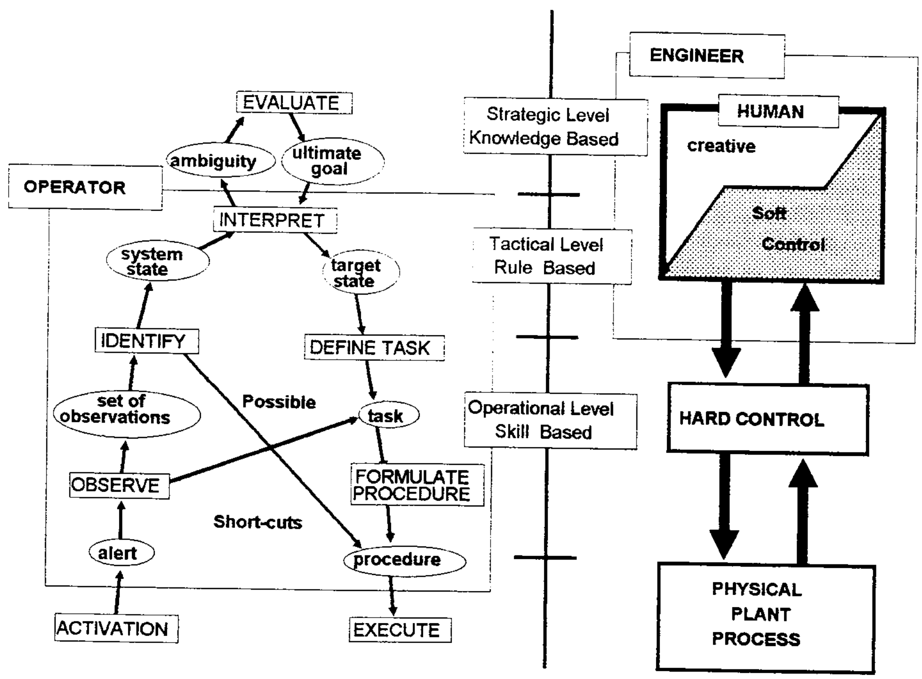

Figure 2: Operator/Engineer/Process solution space.

during a possible upset condition[9]. Hence, which data are given priority depends on context of the process problem and such duties are the concern of the advanced PSS. These PSS assisted operational excursions into the knowledge-based strategic level for the human operator can make this a routine procedure if the operator so desires. (Note that such autonomy from the PSS does not threaten the human operator as it still must take guidance and direction from the user -- the human-centred approach philosophy[1] has not been diminished in any way by the PSS.) Previously, such access only came at the expense of more manpower and effort which seriously detracts from the CRO's already overburdened resources and was only pursued when situations left no other alternative.

In essence then, extension of the PSS can most easily be accomplished through AI techniques. In the simplest of terms, the PSS should not only be concerned with "what" information is presented to the operator but also the "how" of the information transfer. Proprietary research at Simon Fraser

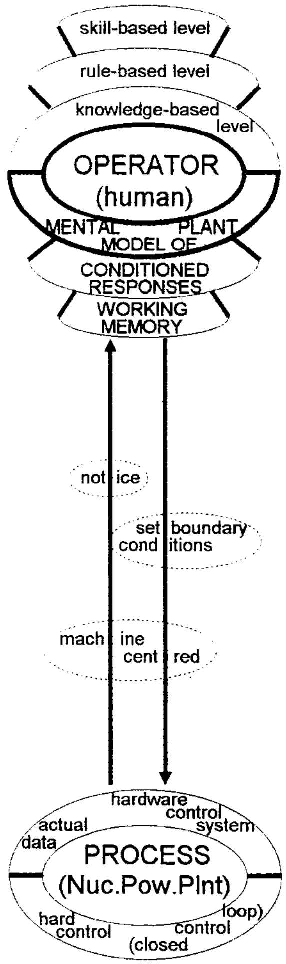

Figure 3(a):Supervisory control and data acquisition -SCADA.

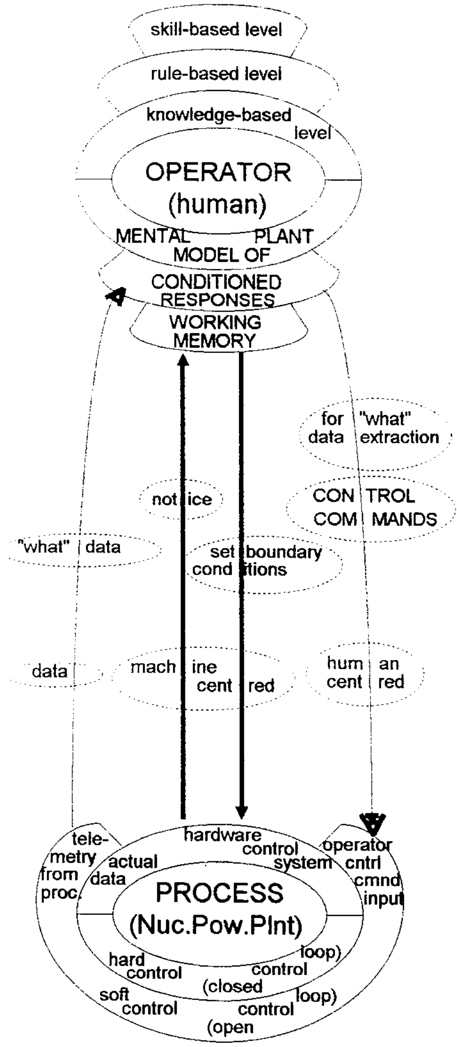

Figure 3(b):Artificial intelligence and supervisory control.

University as part of the IRIS project under Precarn Associates support, already recognized the importance of this distinction for graphical presentation environments; these researcher are using expert system techniques to realize these goals[10,11]. For example, the work of Lupton et al.[12,13,14] on the dynamic priority determination of alarms for presentation purposes which depends on the process status, is a good beginning to PSS. Further enhancements can be made and the OPUS system strives to illustrate the advanced PSS concept.

Implementation Considerations

The sequences delivered in figure 3 serve to indicate the components of the PSS that must be developed. Figure 3(a) illustrates the basic machine centred system which may be compared to the hard control of figure 2. The soft control in figure 2 is shown in figure 3(b) and represents the human-centred approach. Finally, the outer constructs of figure 3(c) give the level of complexity that

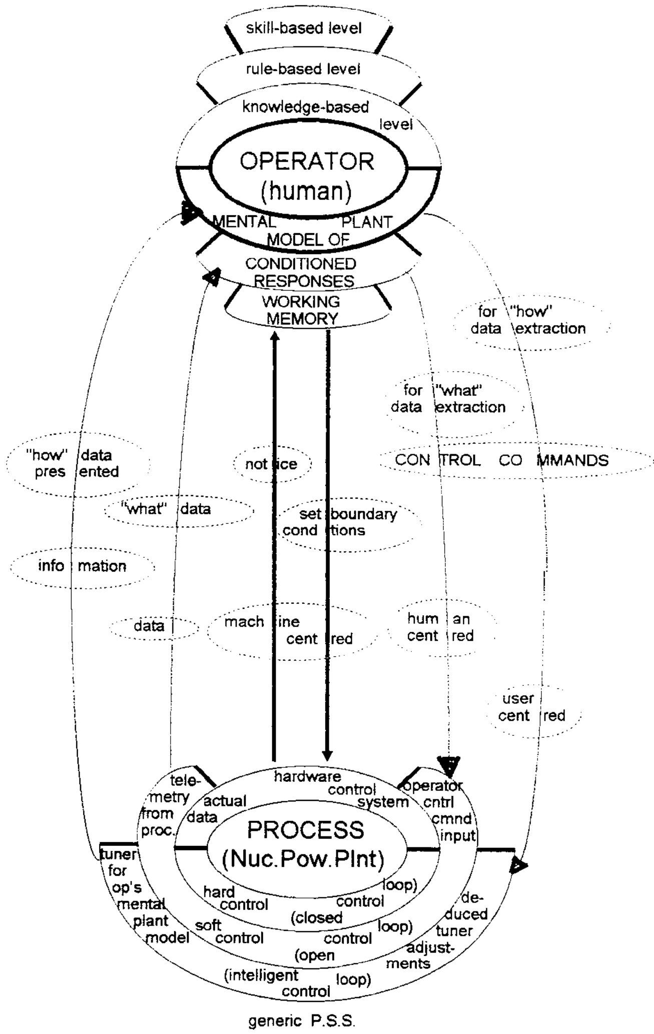

Figure 3(c): AI+performance support systems -PSS.

the PSS must reach to allow the user-centred approach. Conceptually the technique is interacting with the user's mental model of the plant at any given instant. The sensitivity of the PSS to this mental model is implemented through AI-based user modelling techniques [15] where the operator's queries and responses reveal stances taken by the operator and the directions in thinking patterns. Coupled with knowledge of the plant process itself, the PSS is able to present pertinent data on screen and/or allocate more computer resources to problem areas such as simulation and/or calculational procedures.

Such ability for the PSS is not only difficult to produce, but also non-trivial to deliver. OPUS (OPerator/User Support) is a system, being developed at McMaster University, that operates on a distributed system hardware platform and possesses an agent-oriented software architecture. The use of both functional and temporal abstraction techniques [16,17,18] have somewhat blunted the impact of the intensive computational requirements of AI on real-time performance. Further uses of these fundamental design principles in software are already visible in figure 2 where fast algorithmic procedures for process control are vested in the "hard control" box (usually dedicated embedded control computers), while slower, more reasoned procedures for more complex process operations occur in the "soft control" box. Such advancements in system design have been adhered to in OPUS in realization of the difficulty of achieving real-time performance in a complex system[19]. OPUS details have been given elsewhere in this conference[20] but some additional enhancements are also being explored using expert system embeddable shells.

In light of the concern that computer-based decision brings to safety licensing compliance, AI ironically may play a significant role in validation procedures. The OPUS system is being developed with CLIPS [21] (NASA's "C" Language Integrated Production-rule System) to validate conclusions drawn from plant process analysis determined by more traditional methods. This is analogous to the requirement that common mode failures in nuclear systems are minimized by using two completely different physical systems to shutdown nuclear reactors (Darlington's SDS#1 (ShutDown System) is software driven and inserts metallic control rods into the reactor core, while SDS#2 is hardware based and incorporates the injection of liquid absorber into the heavy water moderator). On one hand, OPUS "C" procedures developed under formal semantic rules for regulating safety compliance may warn of a "derate" condition in the process and on a parallel processor, a completely different programming paradigm (expert system inference) can be used to validate results. Also possible with the OPUS collaborating system (concurrently executed on another processor of a multi-computer distributed system using, say, an up-to-date log file or data playback file for analysis) is the provision for process state sensitive on-line help screens as well as operator context sensitive assistance. Note that user queries such as to why a conclusion has been made fall naturally into the expert system repertoire of offerings.

Conclusions

The evolution of AI as applied to the open loop process control regime has taken the field from simple machine-centred supervisory control and data acquisition approaches to advanced user-centred performance support systems where user/operator/machine optimized interfaces are now possible. Here, the spearation of the "what" from the "how" have been realized. In the vernacular "clever people need cleverer machines"[22] whic is now the promise of the future where AI can, at last, play an honest and major role. Eventually, it is hoped that the expert system technique will take its place beside the standard repertoire of tools, as a equal, used by the developer/engineer in the daily pursuit of engineering practice.

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