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The Role of AI in the Engineering Domain:
A Partnership on the Move!

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Abstract

Artificial Intelligence, and more specifically the expert system paradigm, is many things to many people. This paper looks at several University/Industrial interactions through the eyes of a multi-disciplinary group at McMaster University. Industrial research associates have included New Brunswick Power (Pt. Lepreau Generating Station), Canadian Department of National Defence/Defence Research Establishment Ottawa (Nuclear Accelerator Operations), Atomic Energy of Canada, Ltd. (Chalk River Laboratories), Atomic Energy Control Board (Safety Analysis Division), Environment Canada (Wastewater Technology Centre), Zenon Environmental Inc., and Heat Transfer and Fluid Flow Service -- HTFS, Inc. (Chalk River Laboratories, Canada and Harwell, UK).

The above interactions and approaches to developing projects are briefly described with particular emphasis on the benefits expected to accrue from AI and its eventual use. In so doing, the authors draw a correlation between the projected role and the actual role that expert systems play in the engineering domain. One apparent characteristic is that the presence of an inference engine and knowledge base is no longer a prerequisite for "expert system"-like behaviour and hence the query: Is there a role, then, for "true AI" in the engineering domain? The authors contend that indeed the future is brightening. In closing and based on such discussions, the future of practical AI is considered.

Introduction

Artificial Intelligence, and more specifically the expert system paradigm, is many things to many people. This paper looks at several University/Industrial interactions through the eyes of a multi-disciplinary group at McMaster University. Industrial research associates have included New Brunswick Power (Pt. Lepreau Generating Station), Canadian Department of National Defence/Defence Research Establishment Ottawa (Nuclear Accelerator Operations), Atomic Energy of Canada, Ltd. (Chalk River Laboratories), Atomic Energy Control Board (Safety Analysis Division), Environment Canada (Wastewater Technology Centre), Zenon Environmental Inc., and Heat Transfer and Fluid Flow Service -- HTFS, Inc. (Chalk River Laboratories, Canada and Harwell, UK).

It has been our experience that developers are attracted to AI approaches because construction of the knowledge base through some expert system building shell seems intuitive, particularly when inferencing rules can be considered last. The view that rapid prototyping and modular growth are extremely desirable when dealing with unknown factors is prevalent. Also, expectations are based on other perceived AI properties such as the need for either goal or data driven inferences based on a preconstructed knowledge base. The seeming ability to generate more generic or adaptable code from subgoal generation techniques is attractive. As well, the capability of dealing with unbounded states is an anticipated property since the solution structure does not need to be predefined. This is due, in part, to the uncoupled nature between the knowledge based facts and the inference engine.

Case Studies - I

We begin with outlining some interactions and approaches to developing projects with particular emphasis on the benefits expected to accrue from AI (mainly expert systems) and its eventual use.

At the Wastewater Technology Centre in Burlington, Ontario (a former division of Environment Canada, now privately operated), an "expert-on-demand" property was anticipated in the Engineering design and development of METEX, a (gold) Mine Effluent Treatment Expert System [1,2]; however, a PC-based system's shell (Level 5 from Info Builders) eventually became the mechanism to field user enquiries and, in response, extract both data and graphical information from a standard database for screen presentation. In the same field, but more closely allied to real-time tasks, the Zenoview Systems from Zenon Environmental Inc., also in Burlington Ontario, operate water purification equipment via QNX (a real-time Unix-like PC-based operating system from Quantum Software in Kanata, Ontario) and the expert system shell Comdale-X from Comdale in Cambridge, Ontario. This intelligent SCADA (Supervisory Control and Data Acquisition) system operates with sub-second response times and is being enhanced to process control such that, even if unattended, the yield of produced water quality is within specifications. If the water standard becomes non-nominal then alarms for human intervention are raised automatically. Even though the rules within the expert system are relatively simple, the graphical screen-based status displays, including active value sensor readouts is the primary duty of the Comdale software[3].

While on research leave from McMaster University, one of the authors (WJG), set out to capture heat exchanger expert designers' knowledge (at HTFS) via Neuron Data's Nexpert and ended up generating a scorecarding (or rating) technique in the "C" language [4,5]. The other author (WFSP) attempted a real-time process control AI driven system for a particle accelerator [6,7] for some task automation in hopes of alleviating stresses on scarce expert operators; however, the result was to relegate AI to a more traditional diagnostic role and employ object oriented PASCAL for time critical closed-loop control, coupled with an embedded single board computer.

Discussion

In almost all cases, the use of expert system procedures or shells serve to focus the engineer on domain knowledge and heuristic rules. This shallow model approach, using standard engineering practice, is inevitably piecewise refined into the more axiomatic deep knowledge model where the more familiar procedurally oriented methods prevail. In the final analysis, this relegates AI to an ancillary role. It is not, therefore, uncommon in the industrial arena to find an AI touted system or expert system which, in its final form, is actually composed of a "case" construct in "C" or other procedural languages. The presence of an inference engine and knowledge base is no longer a prerequisite for "expert system"-like behaviour.

Is there a role, then, for "true AI" in the engineering domain? The authors contend that indeed the future is brightening.

Case Studies - II

Through the opportunities afforded by a research contract with the Atomic Energy Control Board of Canada (AECB)[8], both authors were able to study several knowledge-based operator aids, mainly for the nuclear power plant industry. Of particular interest is the work of Lupton et al.[9,10] who have approached complex plant operations with a human centred approach rather than a machine centred approach[11]. This is in stark contrast to several years ago where smart AI-driven computers were viewed as a threat to replace human operators, the mellowing of the field as applied to open loop process control is now focusing on aiding the seasoned operator in performance of duties. The research group is developing a prototype for CANDU power plants on multiple workstations where the G2 expert systems shell (from Gensym Corporation), the successor to Lambda Machines Inc.'s PICON, is providing intelligent alarm annunciation with dynamic priority determinations based partly on static/validated priorities and those derived, "on-the-fly", from environmental and plant status conditions at the time of upset[12].

Also examined under AECB auspices was the Intelligent Graphics Interface (IGI) portion of the PRECARN - IRIS research program. PRECARN is an association of industrial concerns who fund and direct important "precompetitive" research in intelligent systems. Although all the IGI work is proprietary, information gleaned from private communications and public documents[13] indicate that the objective of the work, largely carried out at Simon Fraser University (B.C.) under the guidance of Dr.N.Cercone, is to use AI and specifically expert systems to carry out information delivery in a manner that is tuned to the user; that is, IGI is exploring more about the "how" than the "what" of information transfer to the human operator. This is an example of a true human centred system and it is unfortunate that more detailed descriptions are not available in unclassified documents.

While one of the authors (WFSP) spent some period on research leave at New Brunswick Electric Power Commission (NBEPC), he became aware of a project to allow physicists and engineers to taylor a Physicists Analysis Workstation (PAW) into a PC-based engineering analysis platform. Again, of a proprietary nature (system development occurred at Atlantic Nuclear Services Ltd. of Fredericton under contract to NBEPC's Pt.Lepreau Generating Station -- PLGS)[14], the system is being developed to aid in massive data reduction for the megabytes of plant data that is produced daily. Thus the need for a user tunable filter, where the user portion of the problem is critical to successful deployment. For the myriad of operational groups at PLGS clamoring for interesting data, the heart of the duties for PAW is to provide a large dynamic range of data manipulation activities. Note that one group's signal of interest is another's unwanted interference. For example, data on an upset event for the engineering incident analysis group is noise to the core monitoring group who analyze long term trends from the data.) Here it is expected that PAW will employ group specific knowledge bases that will present appropriate tools for a group member to manipulate the data suitably. This is also an instance of more trends towards focussing knowledge-based systems on human centred activities.

And finally, both authors, under a NSERC group strategic grant are developing OPUS, an Operator/User Performance Support System for the Central Sampling System, at the Pt.Lepreau Nuclear Generating Station of New Brunswick Power [15,16]. Initially, expert systems had assumed an ancillary role; however, in order to exhibit more versatility, knowledge-based systems are being explored to provide independent validation capability for licensing compliance considerations and user modeling as a form of enhancing the human centred nature of the software system. For the former, the OPUS system incorporates CLIPS [17] (NASA's "C" Language Integrated Production-rule System) to validate conclusions drawn from plant process analysis and derived 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. Note that this 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) can also provide user help screens where user queries such as to why a conclusion has been made fall naturally into the expert system repertoire of offerings.

Table 1

Comparison chart of systems mentioned in text

Establishment	**System Name**	**Expert System Shell**	**Use**	**Comments**
WTC	METEX	Level 5	dispatcher	handles graphics and database accesses on PC
HTFS/AECL	HTX	In house	calculational	part of general algorithm
McMASTER U.	PACES	In house	diagnostics	Embedded system
CRL/AECL	Alarm Annunciation System	G2	dynamic priority determinations	multiple workstations & its on one.
SFU.	IGI/IRIS	Echidna	user modeling	constraint-based logic formalism
McMASTER U.	OPUS	CLIPS	validation/ modeling	multiple PCs and its on one
ANSL/NBEPC	PAW	Not yet determined	automated data reduction	Automated POI* determinations for analysis on PC
Zenon Environmental	Zenoview	Comdale	process control	so far used for database and graphics on PC

* POI - points of interest

As an aside to the human vs. machine centred trend, consider the PACES work where, goal driven diagnostic AI is used to determine if crash recovery procedures should be used to restart accelerators. Although originally thought to be too slow, the AI system performs as well as a human operator and in the human time frame to solve the problem. In this context, expert systems are not too slow to be of value [11].

Conclusions

In summary (see Table 1), early uses of expert systems have served to focus the problem solver on developing an appreciation for the component parts of the whole solution. In the final effort, through appropriate engineering practice, this solution could and usually is, implemented with traditional programming means. Hence, working expert systems of the past (with only a few exceptions) were only demonstrated with "toy" regimes. By mid-1980s, some expert system building shells touted "real-time" control, such as Texas Instruments' Personal Consultant Plus (PC+) and the "on-line" attachment. Later embeddable shells allowed expert systems to be employed when required and were more capable of accessing commercial databases and spreadsheet information. Extensions to include expertise to be derived from non-human forms were also advanced at this time[18]. And today, this evolution has taken us (see figure 1) to an explicit recognition of the human/machine distinction where input systems have become part of the performance support system regime[19]. Here separation of the "what" from the "how" have become realized. In the vernacular, '"clever people need cleverer machines"[20] which is now the promise of the future where AI, at last, can play an honest and major role. In this milieu, then, we see the gradual trend towards the situation where the expert systems' technique will take its place as an equal beside the standard repertoire of tools used by the developer/end-user engineer in the daily pursuit of engineering practice.

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