Implementing Expert Systems for Process Control

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Introduction

Expert Systems can be used in process control for advisory, analytical, and control functions. Specific examples include advanced control strategies, alarm management and interpretation, operator procedure advisories, process diagnostics, and generation of alarms when the process is approaching the boundary of the normal operating environment.

An expert system encapsulates the problem solving power of a human who has the special knowledge to solve problems of a specific domain. This could be the medical diagnostic knowledge of a physician. It could be the knowledge of a structural engineer who designs off shore oil platforms.

More to the point of this paper, an expert system could use the plant engineer's knowledge of how a plant is supposed to work to solve operating problems. The expert system can also use the senior plant operator's pragmatic knowledge of how the plant actually works and what operating procedures eliminate the most pressing problems.

The plant gains several advantages by using an expert system rather than relying solely on direct human problem solving.

Experts are rare. The senior operator is not always on shift when the problem occurs. The control engineer may not work at the plant where the problem happens. The solution may require the combined knowledge of two or more experts.

People's focuses of attention are variable. The plant operator may not be paying close attention at the time the problem develops, or may focus too long on the wrong hypothesis.

People's scopes of attention are variable. A problem which an experienced operator can solve quickly may be too complex for another operator.

Human response time is limited. If humans can not reliably respond quickly enough to certain problems, the question becomes whether an expert system would be faster.

Human decision making is variable. Sometimes there may be more than one adequate solution to a problem. When an expert picks one correct solution one time and a different one at other times, the solution approach can remain a mystery to someone who watches and tries to learn from the expert. The very act of building an expert system, however, is the act of formalizing the knowledge. This formal representation of the problem solution approach can be a vehicle for studying how to improve the approach.

Expert System Versus Other Software

The forego ng reasons for us ng expert systems app y to other forms of process contro software such as funct on b ock systems and procedura anguages

Funct on b ock systems are des gned spec f ca y to so ve contro prob ems These systems have been ref ned so that they hand e very comp ex contro prob ems They a so a ow the contro eng neer to mp ement contro s n a grammar w th wh ch he s fam ar The more common the prob em to be so ved, the eas er t s to so ve w th funct on b ocks But, when an unusua prob em s to be so ved the use of the funct on b ocks can be very m t ng

Procedura programm ng anguages (e g BAS C FORTRAN C) prov de great f ex b ty But, un ke funct on b ocks they are not the anguage of the contro eng neer Wr t ng the code can take a ong t me Wr t ng these programs takes a somewhat d fferent ta ent from contro eng neer ng Procedura anguages force the deve oper to th nk n terms of procedures even though the contro prob em s probab y not nherent y procedura

The EXPERT 90 process contro expert system deve opment package descr bed n th s paper prov des f ex b ty n certa n areas not prov ded by funct on b ock systems t a ows comp ex og c to be more eas y and understandab y mp emented wh e prov d ng more eff c ent process ng of the og c t prov des og c man pu at ons when the nput data s fuzz er tnan nard og c

The expert system ed tor prov des a anguage wh ch s c oser to the task of mak ng contro dec s ons than are procedura anguages t a ows the app cat on deve oper to d rect y descr be the so ut on to the prob em and e m nates the job of program m ng the prob em so ut on nto a procedura anguage Th s resu ts n dramat c product v ty mprovements n mp ement ng contro strateg es

Special Requirements of Process Control Expert Systems

Expert systems wh ch hand e process contro prob ems must meet a spec a set of requ rements

- Process nput and output
- T me re at onsh ps
- Manage uncerta n data
- Response t me
- Operator nterfac ng
- Know edge eng neer ng nterface

The expert system must access the process nformat on Th s access must be on ne and n rea t me so that the expert system can prov de users w th more answers than quest ons t must be eff c ent so that *t rema ns w th n the capac ty of the commun cat on* system

Data must be represented n re at on to t me Operat ons must take the age of the var ous data tems nto account The expert system may need to recogn ze patterns n the t me trend of data

Re at onsh ps are norma y descr bed n concrete terms even when the actua data s not that certa n For examp e the statement 'tank eve s h gh when eve exceeds 20 feet mp es that a tank eve of 19 90 feet s not h gh Yet a process contro eng neer m ght cons der a eve of 19 90 feet rather h gh A process contro expert system must be ab e to dea w th such uncerta nt es

The expert system must respond n rea t me ts contro act ons and ts operator adv ce must be g ven before the prob em grows and wh e ts output s st va uab e

The operator nterface must be stra ght forward The expert system must not mpose a new set of d sp ays on the operator wh ch are d fferent from the d sp ays used for the rest of the contro system

The know edge eng neer ng too s must be stra ght forward The know edge to be embod ed n the expert system s he d by the p ant eng neer and the exper enced p ant operator These peop e must bu d the expert system n t a y and ma nta n t They must be ab e to use the know edge eng neer ng too s themse ves f a know edge eng neer ng spec a st were requ red the n t a mp ementat on wou d become more expens ve and ma ntenance wou d become mposs b e

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Real Time Challenges

As ment oned before an expert system wh ch so ves prob ems of a process n rea t me has a more str ngent response t me requ rement The spec f c response t me requ rements depend upon the app ca t on An expert system for nterpret ng alarms must hand e many nputs dur ng an upset and produce resu ts n ess than one second By contrast d agnos ng between many k nds of equ pment wear takes a sma er set of nputs and on y needs to be done every few hours

An nference eng ne has a d fferent eff c ency pro b em than does funct on b ock systems Funct on b ock systems typ ca y terate through sect ons of funct on b ocks wh ch the appl cat on des gner has dent f ed The terat on s rout ne and the rea t me cha enge s answered by hav ng the nd v dua func t on b ock hand ers be eff c ent But the nference eng ne does not rout ne y terate through sect ons of know edge nstead t compares the cond t ons of the ru es w th patterns of ex st ng data so t can dynam ca y p ck a sequence of execut on of the ru es n the process t a ocates memory very dynam ca y n t ny p eces but uses most of those p eces very br ef y The nference eng ne has a non tr v a pro b em n recogn z ng wh ch p eces of memory are ava ab e for re use

nference eng nes typ ca y so ve the r memory organ zat on prob em by stopp ng the r process ng of the app cat on from t me to t me to reorgan ze They typ ca y do th s reorgan zat on when prob em so v ng s most ntense because that s when memory s be ng a ocated the most dynamica y Th s approach s not acceptab e for a process contro app cat on t wou d often beg n the ana ys s of a process upset on y to pause for some t me to reorgan ze memory

The s tuat on wh ch a process expert system s eva uat ng may st be deve op ng as conc us ons are be ng drawn n a process upset many process po nts change rap d y They may cont nue to change ong after a d agnos s s requ red of the expert system Yet some of the chang ng data cont nues to be re evant The expert system must present pre m nary conc u s ons w th n seconds But then t must mod fy ts con c us ons as the data cont nues to change t must mod fy ts conc us ons n a og ca and not nde c s ve way t must dea w th chang ng data w thout recomput ng everyth ng from the start

The Inference Engine Integrated into the DCS

To meet these requ rements the expert system must be on ne f a person s requ red to enter the process data nto the expert system as n F g 1a then none of the runt me advantages of expert systems s met At best the system s usefu for ab testing the concept of a prototype know edge base

The popu ar techn que for putt ng an expert system on ne s to run the expert system on a host computer and nterface the host computer to a gateway of the contro system as n Fig 1b Now the data s on ne and benef ts can be rea zed from the automat c nature of the system Unfortunate y th s s at the expense of the host computer and prov d ng nterfac ng hardware and software ncreas ng the commun cat on oad on the system and suffer ng the de ays n data transm ss on mposed by the com mun cat on system The system can be des gned so that the operator can use the standard contro con so e to access the resu ts of the expert system However the expert system she s are norma y offered w th a great emphas s on the presentat ons ava ab e on y through the r own d sp ay term na As such the operator may have to mon tor a term na of the expert system wh ch uses a very d fferent set of convent ons from the standard contro conso e

The EXPERT 90 nference eng ne descr bed n th s paper, F g 1c runs n standard d str buted contro system hardware ts ru es share the same memory as the funct on b ocks t s processed by the same processor ch p The expert system runs as a b ock n the modu e s conf gurat on as shown n F g 2

Embedd ng the nference eng ne e m nates a of the data nterfac ng prob ems The data s a ready n the same hardware modu e There s no add t ona hardware software or transm ss on de ay

The operator s access to the expert system s through standard graph c d sp ays of the contro system conso e To the operator the expert system s a homogeneous part of the contro system

Embedd ng the expert system also has s de benef ts It m n m zes the types of hardware wh ch the p ant personne need to ma nta n t eases the expan s on of the expert system and m n m zes the ncre menta cost F na y redundant expert systems become ow cost pract ca opt ons by us ng the redun dancy features of the d str buted contro system

Knowledge Representation

App cat on know edge the know edge about how to so ve a spec f c prob em s represented as a set of ru es n an expert system the app cat on deve oper does not need to spec fy a sequence of execut on for the ru es Rather each ru e expresses a re at onsh p among nformat on Th s freedom to add add t ona ru es at any p ace s a major factor n the product v ty ga ns afforded by expert system pro gramm ng over procedura anguage programm ng

F g 3 shows a samp ng of ru es Ru es can express og c w th express ons wh ch use AND OR and NOT The operators SET and CLEAR are used when the va ue of the var ab e n the conc us on s to be remembered even after the r cond t ons are no onger true The use of Eng sh ke var ab e names a ows both p ant eng neers and p ant operators to understand the resu t ng know edge base

T me re at onsh ps are expressed both n the con d t ons and the conc us ons FOR n SECONDS n a cond t on makes sure a cond t on s susta ned before tak ng act on JUST NOW s used when on y the tran s t on from fa se to truth s mportant AFTER n SECONDS causes a ag before the conc us on s ap p ed FOR n SECONDS n the conc us on susta ns the conc us on

So et es data s ot certa Fg 4 shows examp es wh ch dea w th th s The expert may say that rpm s unusua y h gh f t s above 250 Th s does not mean that 249 s not unusua y h gh Perhaps 230 s def n te y not unusua y h gh But between 230 and 250 s an uncerta n area The know edge representa t on anguage a ows th s to be expressed and then a ows stra ght forwarc og c ru es to dea w th the part a certa nty

The Engineering Workstation

The p ant eng neer and the sen or p ant operator can deve op the expert system d rect y They are the experts and are a so the peop e who w ma nta n the expert system S nce they are the ones who use and/or benef t from the expert system they persona y know the aspects of the expert system that need to be upgraded, The know edge representat on anguage shou d be kept c ose to Eng sh to avo d mak ng the app cat on deve oper earn an arcane anguage

The app cat on deve oper constructs the know edge base at a workstat on wh ch s separate from the modu e wh ch w execute the know edge base Th s s the same workstat on wh ch the eng neer uses to deve op trad t ona contro funct on b ock con f gurat ons an BM PC AT or compat b e w th 640K memory The workstat on needs to be connected to the contro system on y when the know edge base s be ng transferred Then the workstat on sends the know edge base to the se ected standard contro e modu e n the d str buted contro system When the modu e executes the know edge base the serv ces of the workstat on are no onger equ red

The EXPERT 90 know edge base ed tor gu des the app cat on deve oper through the anguage As statements are entered the deve oper s presented w th menus of the spec f c tems wh ch can be ed ted nto the statement at the current po nt of ed t ng The ed tor keeps track of va ab e names as the deve oper uses them The ed tor recogn zes the type of var ab es from the usage of the var ab e rather than demand ng that the deve ope def ne var ab es before us ng them The ed tor f nds errors as they are typed rather than present ng the deve oper w th a summary of errors at the end of ed t ng

Conclusion

Expert systems can be used to so ve contro pro b ems The rea t me nature of these app cat ons mposes a spec a set of requ rements on the expert system The expert system must access the process nformat on n a t me y manner and must be represented n re at on to t me Conc us ons must be drawn qu ck y

An expert system deve opmer t too has been deve oped to answer these concer ıs The nference eng ne of EXPERT 90 runs n the same d str buted contro system modu e as the convent ona contro Th s e m nates commun cat ons prob ems and g ves the p ant operator a s ng e w ndow to the process The know edge n an expert system s represented as ru es wh ch may nvo ve t me re at onsh ps The ru es may a so nvo ve uncerta n data Know edge bases are deve oped at a standard workstat on wh ch eads the deve oper through the anguage New ru es can be added n any sequence us ng Eng sh ke var ab e names and syntax

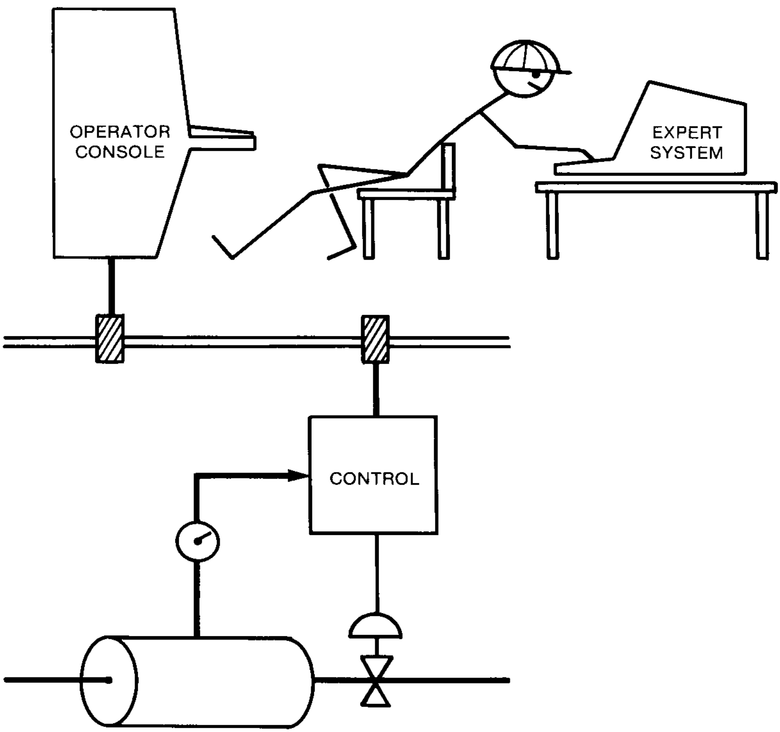

FIGURE 1a Separate Systems

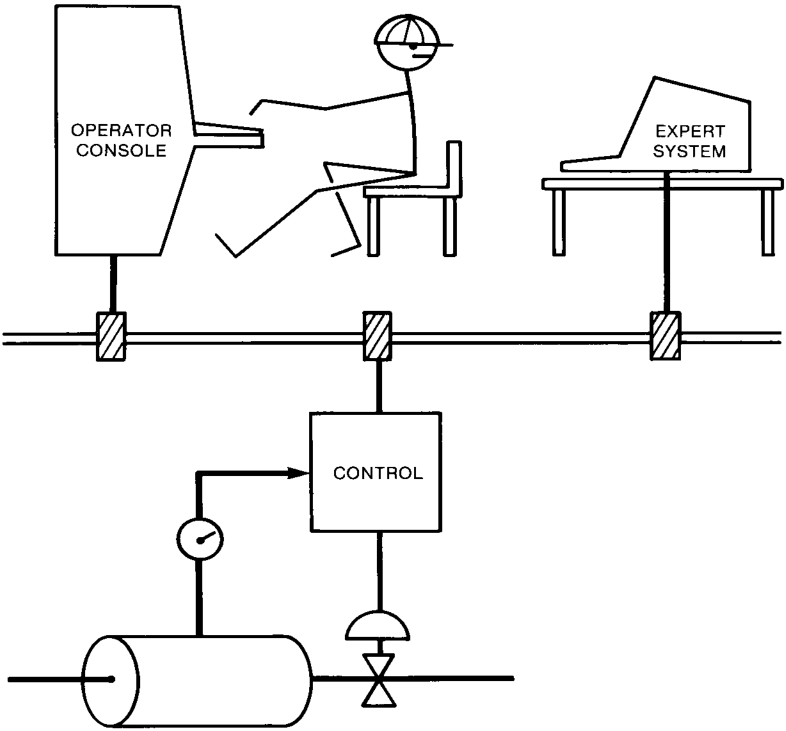

FIGURE 1b   Interfaced Systems

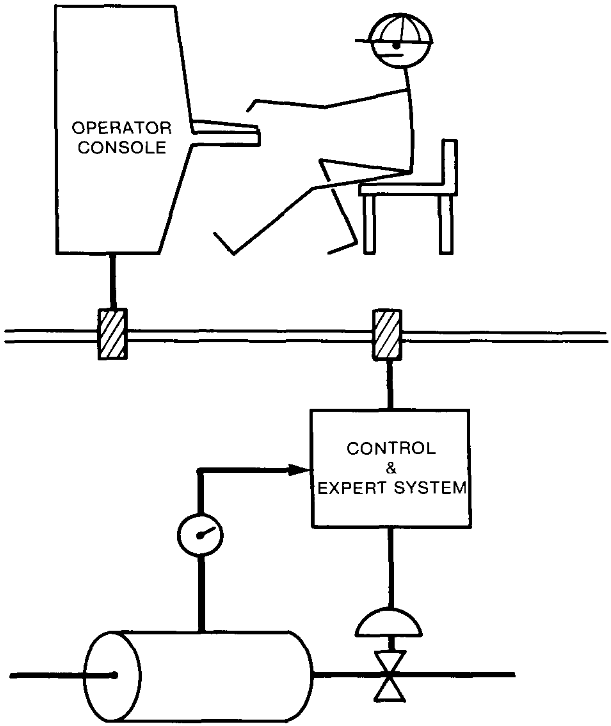

FIGURE 1c Embeded Capability

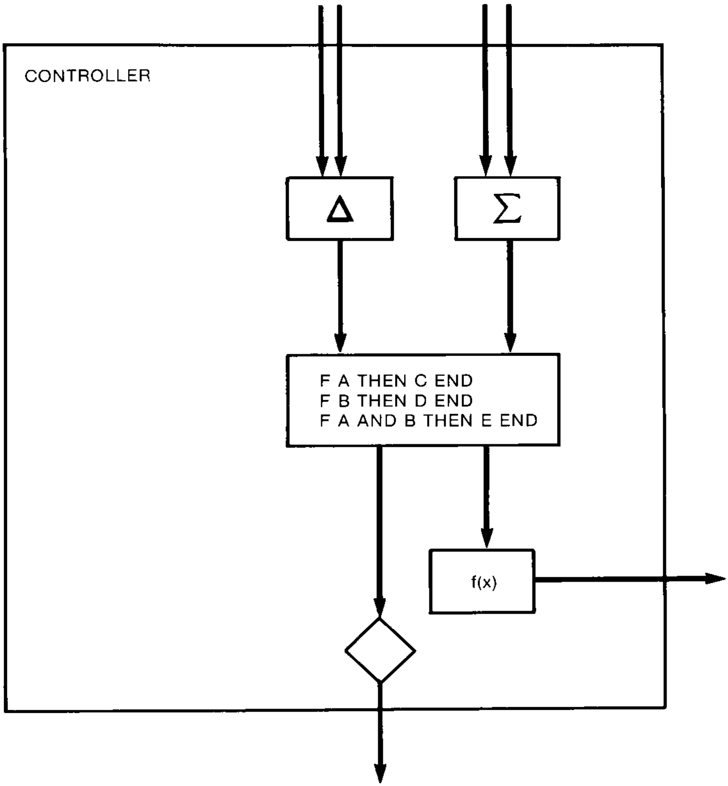

FIGURE 2 Close Up of Controller with Embedded Expert System

```
 F CAV TAT ON   COND T ONS   EX ST
    AND OUTLET   PRESSURE   TOO   LOW
    AND RPM   UNUSUALLY   H GH
THEN PROBABLY   CAV TAT NG
    AND PUMP   WARN NG
END

 F PROBABLY   CAV TAT NG OR PROBABLY   STUCK OR PROBABLY   LEAK NG
THEN SET PROBLEM   S TUAT ON
END

 F PUMP   ON AND NORMAL   PRESSURE   NCREASE AND NORMAL   RPM
THEN CLEAR PROBLEM   S TUAT ON
END

 F FOR 15 SECONDS ((NOT RPM   LOW)
                       AND OUTLET   PRESSURE   TOO   LOW)
THEN PROBABLY   LEAK NG
END

 F PROBABLY   CAV TAT NG
THEN FOR 30 SECONDS  NH B T   PUMP   ON
END

 F JUST NOW PROBLEM   S TUAT ON
THEN FOR 3 SECONDS AUD BLE   ALARM
END

 F ACT ON   REQUESTED
THEN AFTER 60 SECONDS CHECK   ACT ON   COMPLETED
END

 F  NCREASE   FLOW
      AND NOT FLOW   BE NG   MAN PULATED
THEN FLOW   SETTING    (FLOW   SETT NG + 600) / 2
      AND FOR 300 SECONDS FLOW   BE NG   MAN PULATED
END
```

FIGURE 3   Logic and Timing Representation

```
F RPM >230 TO 250
THEN RPM   UNUSUALLY   H GH
END

F PRO3ABLY   LEAK NG
THEN FUMP   PROBLEM
        AND SET PUMP   ALARM
END

F PUMP   SW TCH   ON
        AND RPM   NEGL G BLE
THEN 75% OFTEN PUMP   NOT   GETT NG   POWER
END

F CERTA NTY PUMP   FA LURE > 30%
THEN PUMP   SUSPECT
END
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FIGURE 4   Uncertainty Representation

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