CONTROL EXPERT SYSTEM – THE KERNEL OF ADVANCED CONTROL STRUCTURES FOR CHEMICAL PLANTS

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Abstract. This paper deals a point of view regarding the use of expert systems in advanced process control. There are underlined the characteristics of expert systems as well as some specific architectures for real time expert systems. There are presented the tasks for a control expert system in a Chemical plant (*Catalytic Cracking plant*). The considered control expert system will be able to be built using a commercial expert system shell. This is an empty expert system without any domain knowledge, using only an inference engine and a knowledge representation structure that can be used as building tools for the implementation of an expert system.

1. Typical architectures for expert systems

An expert system is a computer program that uses **ARTIFICIAL INTELLIGENCE** techniques to make decisions or recommendations or predict outcomes based on data analysis. An expert system typically has two parts: a very large database that contains specified knowledge in a given area and a set of rules (called the knowledge base) for reaching conclusions. Expert systems have been applied to chemistry, geology, genetic engineering, medicine, pharmacology etc. .

Usually, the expert system deals with incompletely defined problems or with problems that do not have a classical algorithmic solution. The expert systems for industrial applications solve a wide variety of such problems, among which:

- identifying the process state by analyzing information and knowledge resulted from its observation;
- diagnosis of a system behaviour;
- estimation of a future system evolution;
- process monitoring;
- process control;
- systems projection;
- operators training.

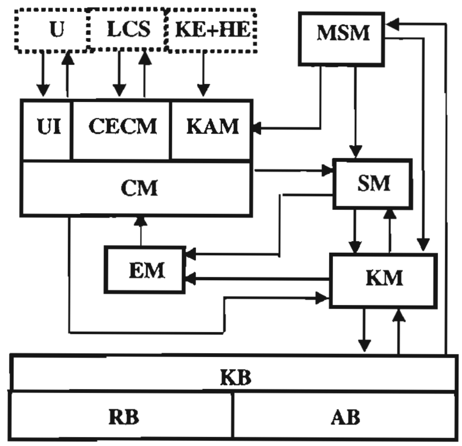

Fig. 1. General structure of an Expert Control System: U – User, LCS – Local Command Structure, KE – Knowledge Engineer, HE – Human Expert, UI – User Interface, CECM – Control Equipments Communication Module, KAM – Knowledge Acquisition Module, CM – Communications Module, MSM - Meta Solving Module, SM – Solving Module, EM – Explanatory Module, KM – Knowable Module, Know ledges Base, KB – Knowledge Base, RB – Rules Base , AB – Actions Base.

Figure 1 shows a possible expert system structure for process control. Any expert system includes three main modules: **knowledge base, inference engine, action base.**

The knowledge base contains specific field information, data rules which the human expert introduces. The knowledge synthesizes object descriptions and the existing relations between these.

The inference engine develops judgments based on knowledge from the knowledge base.

The important operations performed by the inference are:

- selection of a control strategy according to the current problem which has to be solved;
- elaboration of the solving schedule of the problem;
- switch between different control strategy.;
- execution of procedures from the solving schedule;
- generation of control information regarding the processed operations.

The reason capacity of expert systems is based on the separation between knowledge processing and interpreting operations. An inferential mechanism cycle has four stages, performed as follows: *selection, filtration, conflict solving, and execution.*

The action base contains the facts which are associated to the expert system field and modules which can be: *strategical, tactical, operational, special.*

As figure 1 shows, besides principal modules, the expert system structure contains also:

- **MSM** which generates *metarules* (rules for the application of rules in a domain);
- **SM** which chooses the control strategy, elaborates the solving program and helps the expert to check the consistency of the knowledge base;
- **EM** justifies to the user the solution to the solved problem;
- **CM** realizes the communication with: the user, the human expert and with the process that it analyses and commands;
- **UI** is that section of **CM** which realizes the dialogue between the user and the system in quasi-natural language by translating the internal language;
- **KAM** takes the knowledge sent by **KE+HE,** process it and transforms it in a form specific to the expert system;
- **CECM** realizes the interface with the local command structures (LCS).

The performances of an expert system depend both on hardware section architecture and on the software section intelligence level. Among the existing architectures in the expert systems field, **PEER** and **SHELL** are of first interest [5,7].

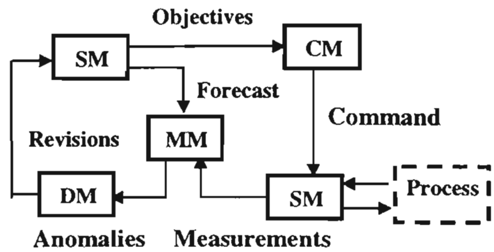

Fig. 2. PEER architecture: SM – Schedule Module, CM – Command Module, MM – Monitor Module, DM.– Diagnosis Module, SM – System Module.

PEER architecture (Planning and Execution with Error Recovery) [7], figure 2, allows the integration of the information technologies specific to the expert system with those of the target domain.

An expert system having this type of architecture includes the following functions:

- activity planning and forecast elaboration – **SM**;
- process and/or activity monitoring – **MM**;
- process and/or activity control – **CM**;
- process's state diagnosis – realized by **DM** through the anomalies provided by **MM**;
- data acquisition from process and commands sent to process with **SM**.

SHELL architecture, shown in figure 3, is characterized by setting the knowledge base out the expert system. Thus, the knowledge base may belong to more expert systems performing the some complex process. The knowledge base update may be realized by any expert systems, through a special module belonging to the base.

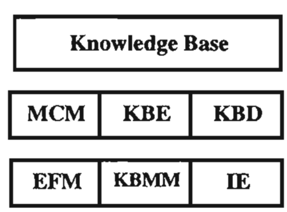

Fig. 3. SHELL architecture: MCM. – Manager Consulting Module, KBE – Knowledge Base Editor, KBD – Knowledge Base Debugger, EFM – Explanations Facilities, Module, KBMM – Knowledge Base Management Module, IE – Inference Engine.

2. Real Time Control Expert Systems (RTCES)

There are many types of expert systems for the control of technological processes [1,2,7], among which are worth to be mentioned:

- RTCES for assisting operators in analyzing diagnosing the plant functioning;
- RTCES intelligent operator assistant type – helps the operator at defining and solving problems;
- RTCES – for process simulation and operators' training and testing;
- RTCES – for the inspection of equipments working in dangerous conditions.

Figure 4 shows the structure of a RTCES, on the same machine finding both the expert system and the control programs.

In this case it's necessary the presence of a multitasking real time executive for which the control task has maximum priority.

Other variant involves the existence of two machines – *host and target machine* – as shown in figure 5.

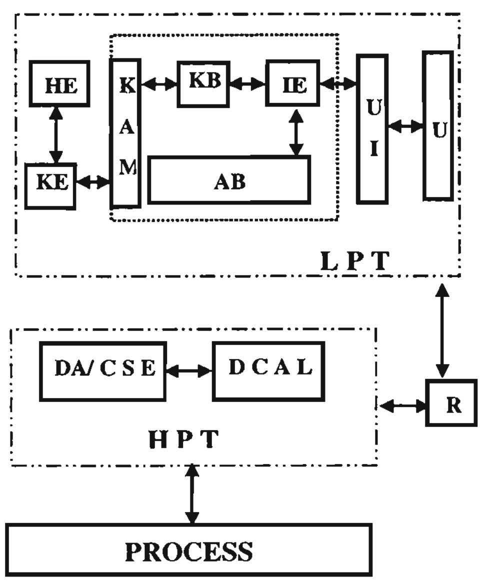

Fig. 4. RTCES architecture: HE-Human Expert; KE-Knowledge Engineer; KAM- Knowledge Acquisition Module; KB- Knowledge Base; IE-Inference Engine; AB-Actions Base; UI-User Interface; U-User; DA/CSE-Data Acquisition/Commands Sender Engineer; DCAL-Digital Control Algorithms Library; LPT-Low Priority Task; HPT-High Priority Task

The acquisition of knowledge is realized on the host machine *(developing equipment)*, and then the knowledge base is transferred on the *target machine*. This kind of expert systems presents the following facilities: *simple functions, a knowledge base stable in time, easy realization, rapid checking*

The present paper proposes the use of Nexpert system [7] as RTCES for a chemical plant (*Catalytic Cracking plant*).

The NEXPERT OBJECT development system is a hybrid expert system building tool that provides a fairly comprehensive environment for application development. It is called a hybrid system because it supports both a rule-based reasoning mechanism and an object-oriented representation scheme. The package claims to implement an "open AI architecture" which allows it to be merged into existing environments; it can respond to messages from the outside world or external programs, which themselves might have been triggered by NEXPERT rules or objects. Features of the package include integrated forward and backward chaining using the same symmetric rule format, automatic goal generation, pattern-matching, interpretations, dynamic creation of objects, classes, and properties, methods, daemons, multiple and user-defined inheritance, and non-monotonic reasoning.

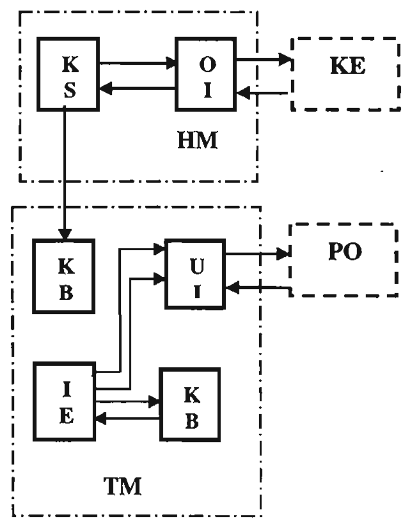

Fig.5. RTCES with knowledge base realized on developing computer (host machine) : KS- Knowledge System; OI- Operator Interface; KE- Knowledge Engineer; KB- Knowledge Base; UI- User Interface; IE-Inference Engine; KB- Knowledge Base; PO- Process Operator; HM- Host Machine; TM- Target Machine.

NEXPERT incorporates a graphic interface, which allows developers and domain experts to edit rules, objects and control structures, and display an overview of the rule and object structures using a dynamic, graphic browsing mechanism. As a consequence of rules being fired, NEXPERT can also display various graphic formats including Windows paint, MacPaint, and TIFF.

The knowledge bases generated by NEXPERT are fully compatible across platforms and upward compatible with new releases of NEXPERT. Knowledge bases can be developed on one variety workstation and then delivered on many other hardware configurations, including such popular platforms as Apollo, AT&T 3B2, and NeXT, as well as less common architectures such as the Macintosh, IBM-PC, VAX, and Sun.

NEXPERT has an application-programming interface (API), which gives the developer access to the functions of the NEXPERT library. External routines written in standard program languages (C, FORTRAN, etc.) can be called from within NEXPERT's rules and methods, or NEXPERT can be embedded within the developer's own application. API externals, which are not interface dependent, are also completely portable across all platforms.

NEXPERT is integrated with standard relational databases and spreadsheets on two levels. The first is through transparent, built-in bridges to spreadsheet formats, such as NXP (the NEXPERT proprietary format), Sylk (Microsoft Excel), and WKS (Lotus), as well as the following databases: DBASE III, DBASE III Plus (DBF Format), FOXBase, NXPDB (NEXPERT's own proprietary database), SylkDB (Excel), and WKSDB (Lotus).

A second level of integration uses separate bridges to connect NEXPERT to the major relational databases on the market (e.g., Oracle, Sybase, Ingres, Informix). Any SQL query can be triggered from within NEXPERT and passed to a DBMS. There is a one-to-one mapping between tables, records, and fields in databases, and classes, objects, and properties in knowledge bases, respectively.

3. Real Time Control Expert System for a Catalytic Cracking Plant

The management of this plant – *the **heart** of any refinery* – when using an expert system has two relevant components: **the quality management** and **the risk management.**

The quality management is of prime importance, as most of the products of this plant being final ones, are directed straight to the market: *petrol, Diesel oil, liquid gases.*

As to **the risk management**, the specific parameters allowed for sections of this plant impose severe restrictions in process's operating. The quality requirements do not have to be considered as a motivation for operating near by the *specified safety limit.*

Plant management is a component of the refinery management because the objectives of the refinery determine the objectives of the plant. This is shown in the *context page* and *level one page* (the figures 6 and 7) for the **IDEFO** model of a refinery [3,6]. ***The actigrame*** from the figure 7 is a component of the *Refinery* module from figure 6.

The knowledge base of the expert system will have to contain mainly information referring to:

- usual quality feed;
- usual catalysts properties;
- specifications of the pant products for different operating types;
- operating strategies focused on the market demands and on the feed availability;
- operating strategies in normal starting and stopping of the plant;
- operating strategies for a forced stopping of the plant.

An important component of the plant is the GASCON section (*GAS CONcentration)*, which produces C_3 and C_4 fractions. In GASCON structure the *propane - propylene* separating column is a major part. In the last years the specialists from the Automatics and Computers Department, from University "Oil – Gas" Ploiesti, with the author's contribution, elaborated and implemented for this column an advanced control system [4]. It is an hierarchical system, organized on three levels:

- feedforward control;
- automatic tuning for the feedforward control model;
- optimal control.

One of the inputs for this system is specified concentration of propylene in distillate (x_{Di}). The value of this parameter is imposed by the propylene destination. That's why when integrating *Advanced Control System* in *Control Expert System,* the value of the x_{Di} parameter will be provided by the **quality management.** The *Advanced Control System* will send "in exchange" to the quality management the values of the operating spendings and of processing loss in the conditions of the optimal control.

Regarding the **risk management**, it will have to be taken into account the main risks sources in the plant: *reactor – regenerator group, GASCON, CO Boyler, etc.* For every of this sections, the expert system will provide specific intervention strategies in case of critical situations. An important section of the risk management will be to the one referring to the operators' training. An operator training session involves the solving of a *critical situation* (by a succession of simulated manoeuvres) in real time.

The off-line facilities offered by the control expert system include also the execution of simulations programs. One of reasons for the simulation is determination of the adequate control structure, for an imposed situation. Taking into account that the new technologies used at control devices manufacture are with logic programming, the implementation of the structure resulted from simulation is immediate.

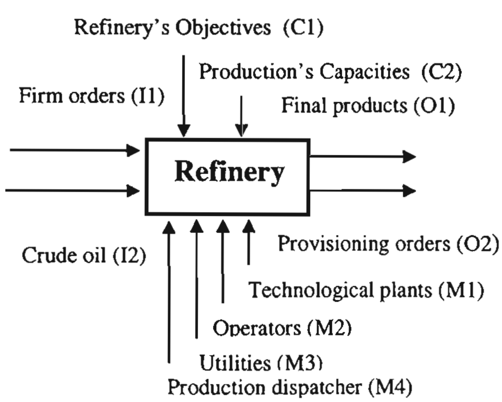

Fig. 6. IDEF0 model for a refinery: context page.

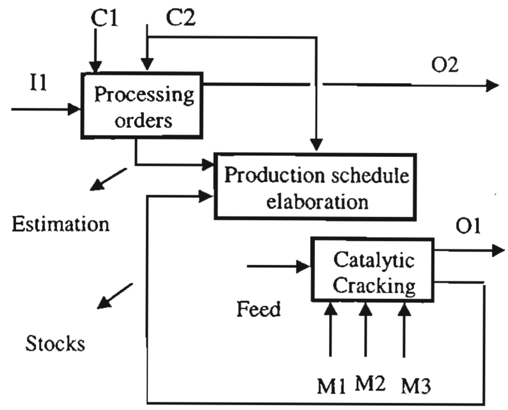

Fig. 7. IDEF0 model for a refinery: level one page.

The expert system will be able to be developed on a Nexpert kernel, also presented in the paper. Using the *fill in the blanks* principle, it will be generated a Control Expert System with a convenient cost – performance ratio.

4. Conclusions

An important advantage using the expert system is that it encodes knowledge representations and decision – making capabilities in order to allow intelligent decisions and recommendations automatically. In contrast with hard – wired logic, sequencing circuits and sequential programs, heuristics represented as rules offer flexibility and versatility.

The control expert system will be designed according to the main parts of a Catalytic Craking plant: *reaction section, separating section, gas concentration section, CO Boyler.*

This Control expert system will integrate the hierarchical advanced control system developed with the author's contribution for propane – propylene separation column (from gas concentration section) The designed Control expert system will be incorporated in the refinery's management information system.

5. References

[1]. U. Brehaus U. *Use of Object Oriented Software Metodology to Design of Expert Control Systems.* www.lbl.gov/LBL-Publications/procPS4/Software-Metodologies/Ab195es5.html

[2]. D.I. Carstoiu *Sisteme expert*, Editura All, Bucuresti, 1998.

[3]. G.I. Filip *Informatica industriala. Noi paradigme si aplicatii.* Editura Tehnica, Bucuresti 1999.

[4]. N. Paraschiv, V. Cirtoaje *Sistem automat evoluat pentru procesul de separare a propenei de chimizare – Implementarea industriala.*, Revista de chimie, Nr. 7 , 1992.

[5]. I. Popa *Inginerie software pentru conducerea proceselor industriale*, Editura All, Bucuresti, 1998.

[6]. F. Vernadat *Enterprise Modeling and Integration - Principles and Applications*, Chapman & Hall, London, 1996

[7]. D.A. Walerman *A guide to expert systems*, Addison Wesley Book Company, London 1997.

[8]. P.K.Yue P.K. *Application of Expert System Metodologies to Real time Process Control.* www.geocities.com/Tokyo/Temple/1053/expert.html