A KNOWLEDGE BASED ON-LINE DIAGNOSTIC SYSTEM FOR THE FAST BREEDER REACTOR KNKII

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Abstract

In the nuclear research center at Karlsruhe, a diagnostic expert system is developed to supervise a fast breeder process (KNKII). The problem is to detect critical phases in the beginning state before fault propagation. The expert system itself is integrated in a computer network (realized by a local area network), where different computers are involved as special detection systems (for example acoustic noise, temperature noise, covergas monitoring and so on), which produce partial diagnoses, based on intelligent signal processing techniques like pattern recognition.
Additional to the detection systems a process computer is integrated as well as a test computer, which simulates hypotetical and real fault data.
On the logical top level the expert system manages the partial diagnoses of the detection systems with the operating data of the process computer and to produce a final diagnosis including the explanation part for operator support.

The knowledge base is developed by typical Artificial Intelligence tools. Both fact based and rule based knowledge representations are stored in form of flavors and predications. The inference engine operates on a rule based approach.
Specific detail knowledge, based on experience about any years, is available to influence the decision process by increasement or decreasement of the generated hypotheses. In a meta knowledge base, a rule master triggers the special domain experts and contributes the tasks to the specific rule complexes.
Such a system management guarantees a problem solving strategy, which operates event triggered and situation specific in a local inference domain.

1. An on-line expert system as an integrated computer network

During the last years, many experiments and system developments concerning surveillance methods were realized in the nuclear research center at Karlsruhe. The systems are stand alone and there exists no connection between them, neither in form of data transfer nor in form of a logical correlation.
Since 1986 a diagnostic expert system is in development. The efforts concern an intelligent global core surveillance at the Fast Breeder Reactor "Kompakte Natriumgekühlte Kernreaktoranlage" (KNK II), which is used as a test facility for all experiments by the separate detection systems. The expert system is implemented as a prototyp.
Two logical functions are integrated in the expert system:
-- Early diagnosis (diagnosis and prediction)
-- Scram analysis (diagnosis after a scram)
During operation of KNK II, the early diagnostic function is responsible to detect anomalies and disturbances in the beginning state, so that a propagation can be prohibited.
The data are available from the process control computer and from the separate detection systems. While the process control computer gives the messages about process parameters, valve states and armature descriptions, the detection systems produce partial intelligent preprocessed data (for instance generated by pattern recognition methods [2]), which have to be correlated in a higher level, the expert system.
To simulate real process data and to test the concatenation of the detection system with the

expert system, a test system is implemented on a VAX computer under the UNIX environment.

On the communication level, all stand-alone systems are connected via a local area network on IEEE 802.3 with the aid of a higher communication protocol, based on the "Transmission Control Protocol/Internet Protocol (TCP/IP).

Figure 1 shows the integration of the expert system and the stand-alone components to one global distributed surveillance system.

2. Logical functions of the expert system

The expert system kernel contains two logical functions: the "scram analysis" and the "early failure detection".

Concerning the "scram analysis", a hierarchical knowledge base is developed, structured by device classes. After a scram, the inference engine generates immediately a cause-consequence fault chain, regarding the time dependent occurence of the events. So the original cause of the scram can be detected. A following "after scram analysis" supports the operator by controlling the function of the process in the new situation.

The aim of the "early failure detection", is to recognize critical process states in the anomaly domain, not yet in the fault propagation mode. To reach that, the inference engine works under two aspects. Observing any fault types and the stored knowledge about fault propagation, following disturbances can be preestimated. That means a qualitative prediction of faults. An other method is to generate quantitative predictions about the process parameters based on histories.

2.1. The logic of scram analysis

Getting a scram, a lot of messages is produced, which has to be analysed by the operator. Important messages have to be discriminated from less important and original conditions must be found, which provide the scram. Especially, the temporal first combination of sufficient conditions must be found.

The logic is implemented by a gate network in form of frames and rules. Different conditions of process states and measurement systems activate the shut down (figure 2).

After a transformation of the logic by the distributive law for sets, we get an ensemble of AND-conditions. Based on time attributes and a forward search algorithm the earlearst AND-combination can be detected, which was sufficient to perform a scram.

The explanation part of the pure diagnostic system is integrated in the graphic network, as well by constructing a fault tree with the described events in a cause consequence chain (figure 3).

After the scram analysis, a so called "after scram analysis" is automatically activated. It is possible to control the correct function of the reactor process system after shut down, that means to control any regulation functions and to supervice parameter changes, which are expected after a scram.

2.2. Fuzzy reasoning and representation for the detection systems

Concerning the early failure detection, reactor expertise is distributed on any experts, each producing preprocessed data sets referring a special detection system. Partially, there exist the same measurement vaariables for different detection systems, partially they are disjunct. So, it seems useful to have detection invariant parameter classes, where special instances are generated when necessary.

In the detection systems are used following classes of parameters (types)

1. Physical parameters
These parameters are observed data of the reactor process, where the predications about the parameters are fuzzy because of measurement faults as well because of the incorrect evaluation of these data.
Examples aré pressure, temperature.

2. Modell parameters
Instances of this type are synthetic measures, the fuzzy aspect is dependent on the stochastic data series while regarding the historic process data, the model approach and the correspondend evaluation.
Examples are estimated order parameters of differential equations, delay factors.

3. Plant parameters
At time, there exist only exact parameter values, which describe any devices like "valves open", "relais closed".

Each of the three parameter types has (dependant on the semantic) a set of predicates, evaluations and qualifications. The predicate is an attribute of the parameter class. The evaluation is a possible linguistic value of the predicate. Each predicate has a special evaluation set. The qualification is a truth measure, belonging to an evaluation of a predicate (figure 4).

The advantage of the structure in model types, predicates, evaluations and qualifications is to have the possibility to generate and to update incrementally any further statements in a fix frame.

2.3. Integration of the scram analysis and the early failure detection system

The aime of the early failure detection is to recognice dangerous states in the beginning phase, that means features in their anomaly domain can be detected as anormal states. Such a surveillance is done by the early failure detection system. By a rapid changement of the parameters or an event, which is sufficient to provide a scram, the reactor shut down. These messages from process computer activates the process of "scram analysis", followed by the "after scram analysis". In opposite of the normal surveillance (early failure system) the "scram analysis" works automatically.
The following figure shows the event triggered activation of the different logical expert system functions (figure 5).

3. Knowledge processing for different domain experts

The knowledge base is developed by typical Artificial Intelligence tools. Both fact based and rule based knowledge representations are stored in form of flavors and predications. The inference engine operates on a rule based approach. The whole inference engine is subdivided in several rule parts. As special domain experts they use the knowledge base and work semantic local. Examples are the surveillance of the pumps, the reactivity and the regulation of the reactor process.

An other semantic part of the domain experts is represented by the ensemble of the detection systems, which produce partial diagnoses using special intelligent preprocessing techniques (for example acoustic noise, temperature noise, covergas monitoring and so on). Specific detail knowledge, based on experience about any years, is available to influence the decision process by increasement or decreasement of the generated hypotheses. In a meta knowledge base, a rule master triggers the special domain experts and contributes the tasks to the specific rule complexes.

Such a system management guarantees a problem solving strategy, which operates event triggered and situation specific in a local inference domain (figure 6).

3.1. Domain experts for the process computer

Important measurement variables are reactor power, core inlet temperature, various pressure components in the loop systems, rotation of pumps and more. These variables are on-line supervized. In combination with the state parameters, trends may be analyzed and future pattern can be preestimated (see table 1).

Tab. I: Domain experts for the process computer

3.2. Domain experts for the detection systems

An other type of domain experts is represented by the detection systems. Partial preprocessed knowledge is available. The predication is performed on symbolic values. To perform a quantitative prediction a transformation of the linguistic evaluations into n-dimensional features is necessary. Each component of the features describes a special evaluation of a process parameter or state parameter. The AND-Operator of all conditions, which influence the failure or anomaly state, is done by the numerical vector representation. So, analytical methods can be applyed, to analyze the instantaneous state and to have a measure for the distance between the process state and any failure mode.

Anomalies and faults are derivated from the preprocessed data of the various detection systems. A detailled description of the realized detection systems is contained in [1]. The most important measurement methods, which are regarded as input systems for the expert system, are:

- Acoustic Noise (AN)
- Temperature Noise (TN)

- Flow indirect, mean assembly temperature (FITM)

Each detection system is regarded as a domain expert, where the local inference mechanisme produces different fault types, regarding special parameters as well as any linguistic expressions (table II).

4. Conclusion

1. The expert system is implemented as prototyp on a LISP machine, especially the scram analysis function, which analyses the cause consequence after a scram.

2. The on-line connection between the test system (VAX computer) and the expert system is implemented. The expert system is supplied on-line with simulated process faults. The knowledge base is updated automatically and the inference machine analyse the fault chain by the diagnostic rules.

3. A small knowledge base concerning the early failure detection is implemented for the four domain experts of the process computer.

5. References

[1] GMEINER, L. (Ed), "Microprocessor-Integrated LMFBR Core Surveillance" (in German), KfK-Bericht 3749, Kernforschungszentrum Karlsruhe, Karlsruhe (1984).

[2] SCHERER, K.P., "Pattern recognition and prediction methods in parametric signal models for early fault detection", KfK-Bericht 4197, Kernforschungszentrum Karlsruhe, Karlsruhe (1987).

[3] SCHLEISIEK, K., et al. "Development of modern signal analysis for surveillance of sodium cooled reactors" (in German), Deutsches Atomforum "Mensch und Chip in der Kerntechnik", Bonn (1987).

Figure 1: A concept of the distributed system

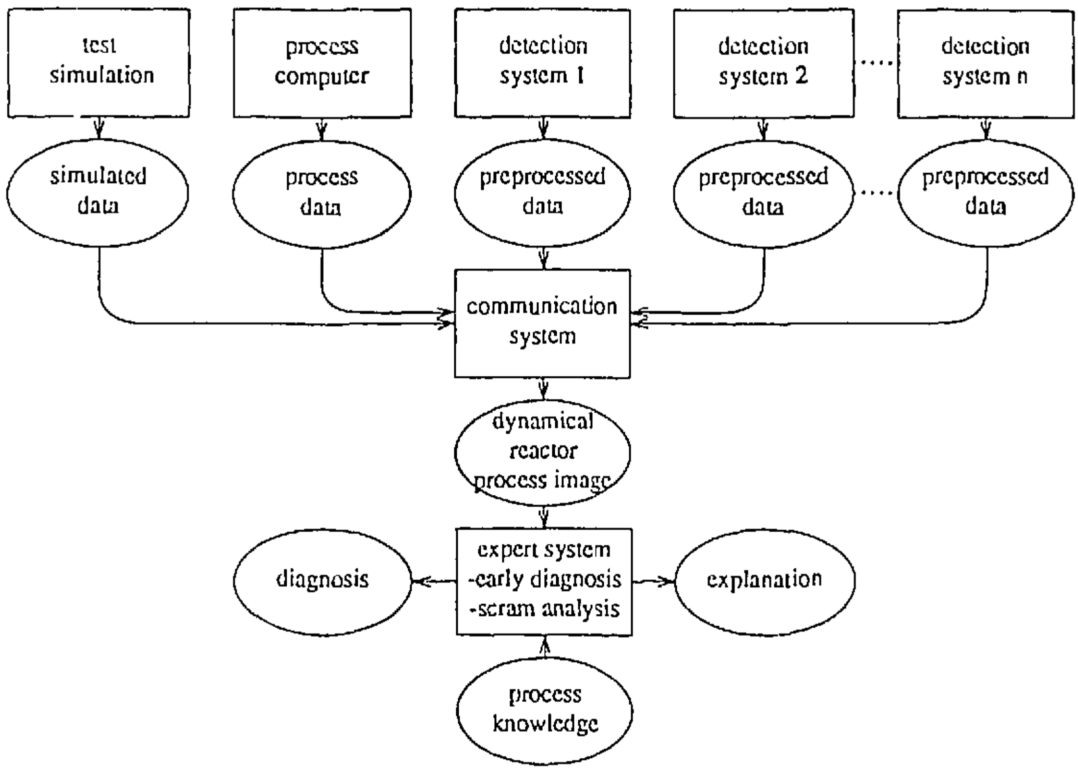

Figure 2: Scram gate network

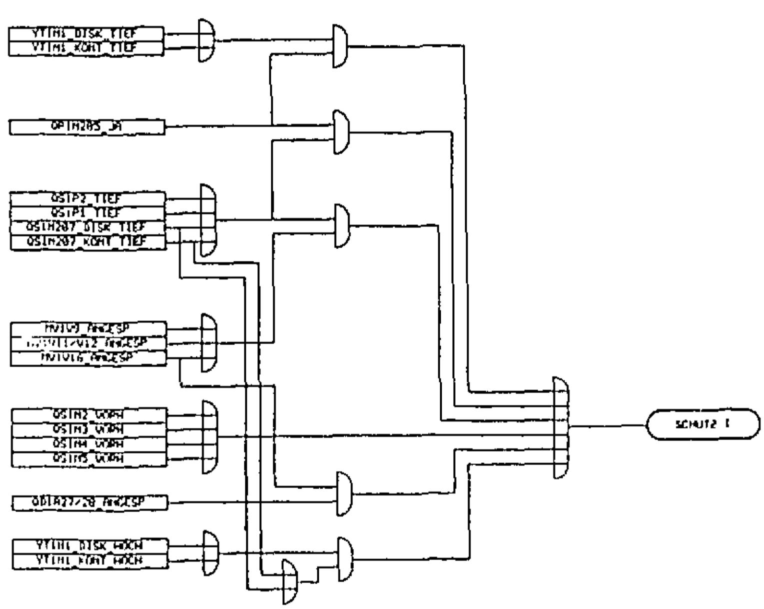

Figure 3: Time dependent fault chain, sufficient for a scram

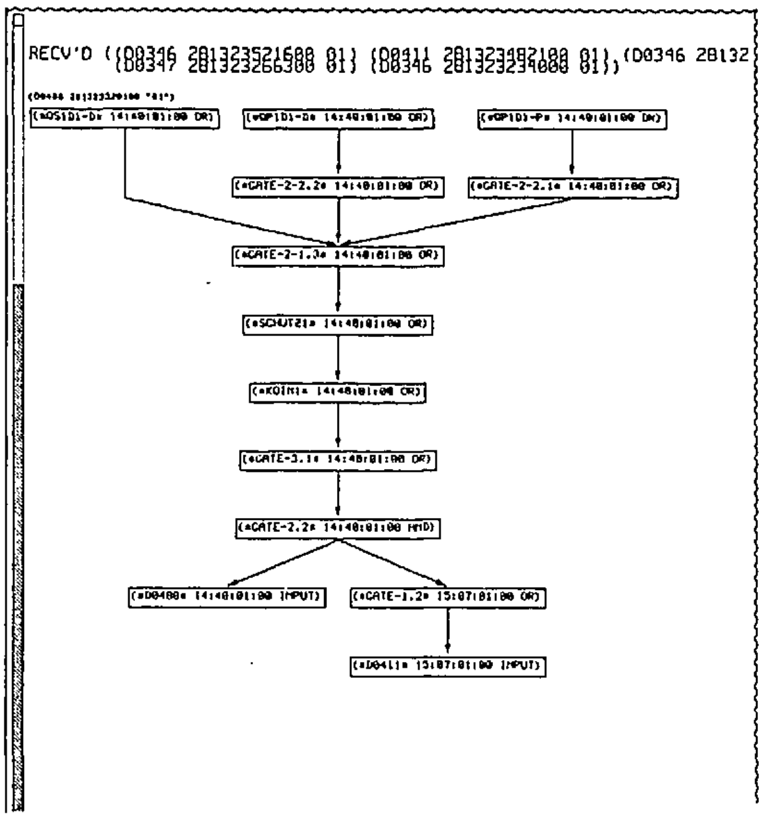

Figure 4: Parameter types and their semantic

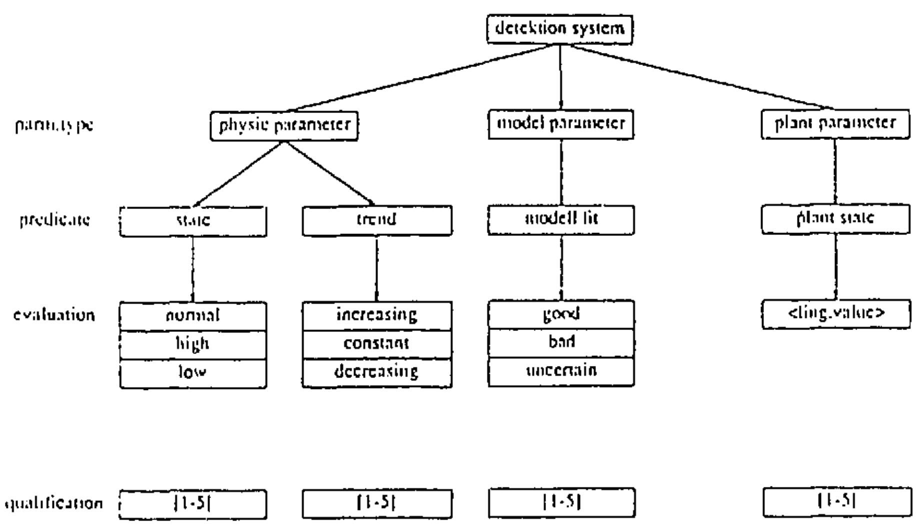

Figure 5: Logical expert system functions

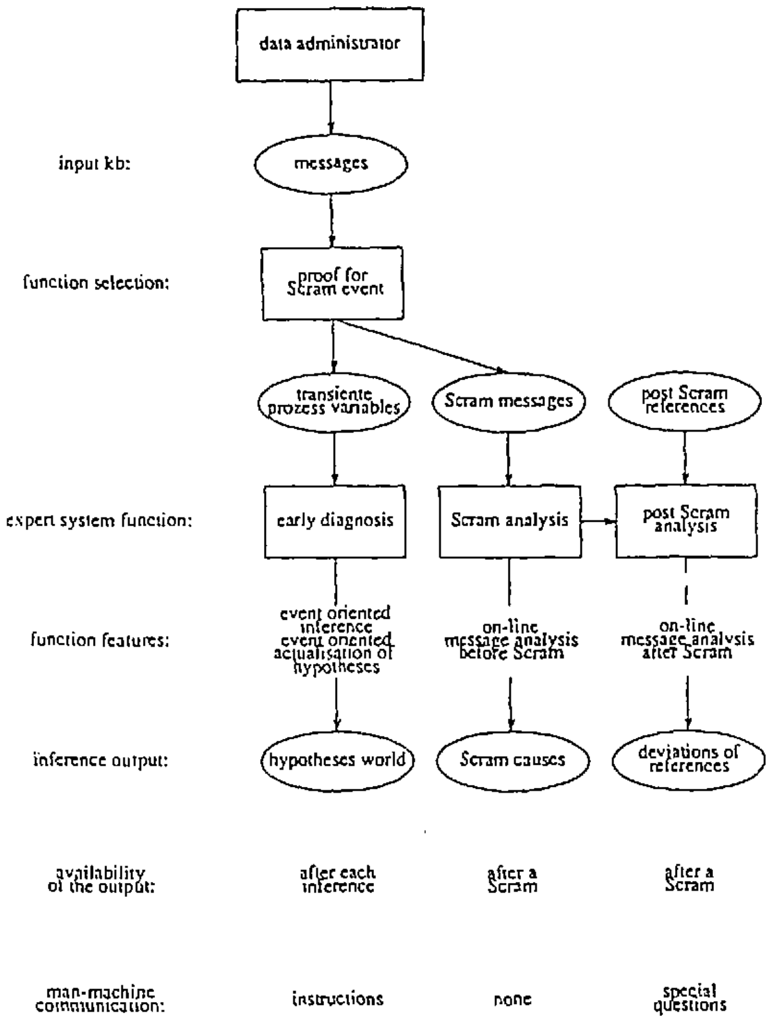

Figure 6: Domain experts in the diagnostic part

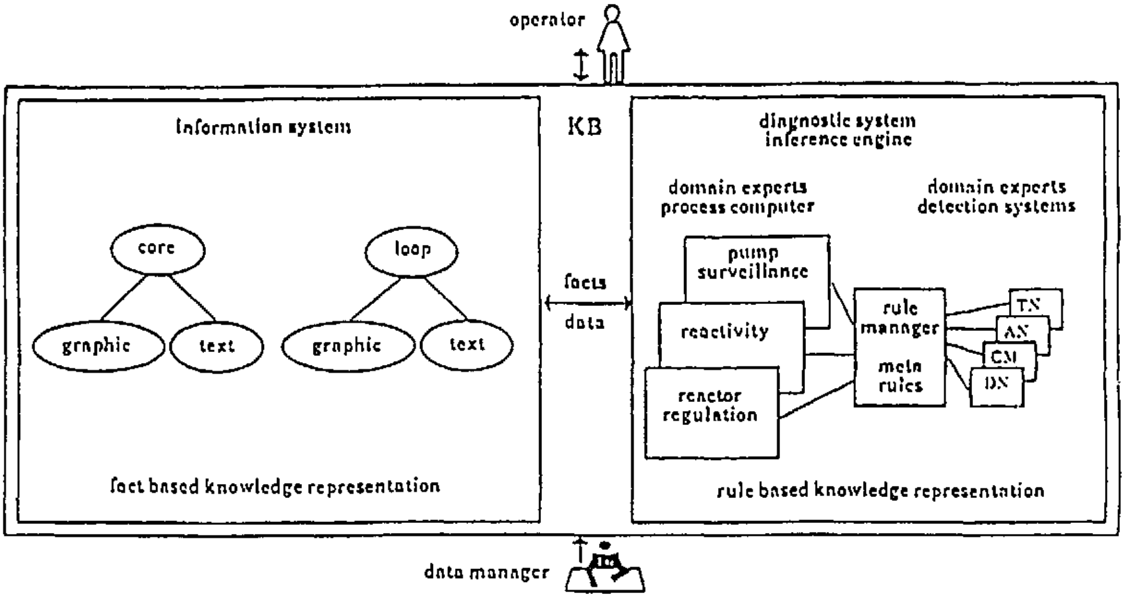

Table I: Domain experts for the process computer

process states		surveillance variables					
domain expert	diagnostic type, instruction	P1Q	S1Q	N	I1	R	dTBE
pump surveillance	prim.pump increasment	*	*		*		*
	sec.pump decreasment	*	*		*		*
reactivity	incorrect input REBI					*	
	control the function f(N)					*	
regulation	check the regulation			*			*
	nominal value changed			*			*

Table II: Domain experts for the detection systems

process states		surveillance variables				
domain expert	fault type	RMS	k-factor	Tk	TV	expression
acoustic noise (AN)	leaker	*				*
	loose particles	*				*
	local blockage	*				*
temperature noise (TN)	inactive global blockade		*			*
	fault in bundle		*			*
	leaker		*			*
Indirect flow (FITM)	reactivity faults			*	*	*
	blockage			*	*	*
	vibrations			*	*	*