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THE USE OF EXPERT SYSTEM FOR MARINE DIESEL ENGINE DIAGNOSIS

ABSTRACT

The paper presents a diagnostic system for marine diesel engine based on an expert system model. The research relevant to knowledge acquisition for this system was done, knowledge data set was built and general structures of the expert system was proposed. Basic sources of knowledge which can be used for construction of knowledge data set are also identified. The basic knowledge related to the diesel diagnostic was undertaken from experts and diagnostic data base. The paper questionnaire was used to the knowledge acquisition from experts. The basic knowledge related to the marine diesel exploitation was undertaken. The rule induction algorithms was used to knowledge acquisition from data base. During the experiment efficiency of LEM induction algorithms was compared to new MODLEM and EXPLORE algorithms. Training and test data were acquired from experiment on marine engine Sulzer 3AL 25/30.

Keywords:
technical diagnostic, expert system, marine diesel engines.

INTRODUCTION

The development of diagnostic systems for marine diesel engines is vital for both ship safety and economic reasons. Nowadays, many diagnostic systems have been created by both research laboratories and engine producers. Typical disadvantage of most systems is their completeness. This means that diagnostic algorithms of technical conditions, adopted during system creation, cannot be updated or modified during later operation.

The solution to the problem could be an expert system in ship engine diagnosis. Module system structure, and above all, the separation of database from remaining program, enables creation of diagnostic system of open type, where diagnostic knowledge can be updated and cumulated.

This paper presents diagnostic system concept, for marine diesel engine, basing on expert system model. The relevant knowledge database was created with use of collected diagnostic data.

Diagnostic data were collected from experts (ship engine professionals) and diagnostic databases.

COLLECTING KNOWLEDGE FROM EXPERTS

The survey was to collect declarative opinions, useful in technical analysis of engine condition. Collection was made in a fashion where knowledge database programmer played a vital role [2]. The programmer was responsible for the interpretation and aggregation of collected expert opinions.

The survey was to obtain operational knowledge information in the form of diagnostic relations, like 'damage — damage symptoms'. Along with operational knowledge, collected information included basic appliance instructions, necessary for storage format of diagnostic report. Basic knowledge included dictionaries of object names, object property names, as well as, terms indispensable for data storage. Expert data were collected during Questionnaire Interviews [5]. The questionnaire questions were tabled. Malfunction listing was created on the basis of problems addressed in professional literature [1, 7]. Questionnaire used open questions with an option of entering new malfunction names by the respondent. Survey experts were chosen on the basis of having at least second mechanic license with two years occupational experience. 36 experts took part in the survey.

The questionnaire included malfunctions of the following engine components:

- fuel system;
- crank-piston system;
- combustion chamber;
- turbocharging system;
- starting-reversing system;
- cooling system;
- lubrication system.

Each expert was to name malfunction symptoms in relevant blank space of his questionnaire form.

Results made up 35 diagnostic rules. The rules included combined premises concluding on technical conditions of particular engine system.

Obtained sets of rules were verified in compliance with the procedures proposed by W. Moczulski [2]. Single rules were verified by experts, by ranking them with degree of conviction on their validity.

COLLECTING KNOWLEDGE FROM DATABASE

The target of the survey was to obtain rules enabling diagnostic of technical conditions of a marine diesel engine on the basis of exploitation information, available in database. Each set of rules was determined with automatic induction method. LEM2 [6] classical algorithm results were compared with MODLEM [6] and EXPLORE [6] algorithms results. The assessment of rule induction algorithms was made with the use of data obtained in active experiment on a laboratory engine.

The engine tested was a four stroke Sulzer 3Al 25/30, of nominal power *Nn* = 408kW and *n* = 750 rpm revolution. The engine was fitted with a measurement system enabling reading of basic operational parameters, like pressure and temperature of combustion gases, charged air, coolant and lubricator. Additionally, taken were fast-changing pressure measurements in engine cylinders and fuel lines. All parameters were automatically saved in a database integrated into measurement system.

The research program was conducted according to active experiment principles. During the experiment, each time, one level of particular malfunction was simulated and all parameters were measured, with engine working within 50 to 250 kW range. The experiment excluded simultaneous presence of multiple malfunctions, as well as, different ranges of particular malfunction.

The following malfunctions were taken into account:

— air compressor efficiency drop;
— turbocharger filter contamination;
— air charger cooler contamination;
— exhaust duct contamination;
— injection pump leakage;
— diminished injector opening pressure;
— clogged injector nozzle;

— badly calibrated injector nozzle;
— leaky cylinder head.

Measurement results were saved in the database and converted to a decision table. Such a form of data presentation is required by adopted rule-induction algorithms. In such a situation, instructing examples are presented in the tabled verses, together with a set of attributes. One of the attributes is decisive, and qualifies a particular example to particular class of decisiveness [6].

The obtained table includes 454 instructing examples, where each of them is represented with 43 numerical attributes. Examples related to 9 simulated engine malfunctions.

Because algorithms LEM2 and EXPLORE should not be applied directly to numerical data, initial discretization was employed. Investigated induction algorithms were applied both to non-discretized and discretized data.

Survey software, named ROSE2 was prepared Institute of Intelligent Systems of Decision Support at Poznan College of Technology [3, 4].

Evaluation of rule sets was made with regard to classification. It means that verified classifier was each time created basing on rules. Presented in table 1 are the rules and right classification choices obtained with 10-fold cross validation technique for investigated rule-induction algorithms. The results of classification are presented in Table 1.

Table. 1. Classification results obtained with different algorithms

No.	Initial discretization	Induction algorithm	Number of obtained rules	Percentage of correctly classified examples [%]	Percentage of incorrectly classified examples [%]	Percentage of non-classified examples [%]
1.	None	LEM2	178	24	32	44
2.		MODLEM	35	87	2	11
3.		EXPLORE	5	21	76	3
4.	Local Method	LEM2	56	91	9	0
5.		MODLEM	46	91	9	0
6.		EXPLORE	300	74	26	0

Source: own study.

Obtained results indicate high efficiency of MODLEM algorithm in case of non-discretized data. The obtained classification accurateness, estimated with 10-fold cross validation technique, was 87%. Classification accuracy obtained with LEM2 algorithm was, in this case, 24%, while in case of EXPLORE algorithm, in 21%. In the case of initial digitalization conducted with help of LEM2 and MODLEM algorithms, identical results were obtained. The lowest accuracy was obtained with EXPLORE algorithm.

One doubtless advantage of MODLEM algorithm, comparing with LEM2, is direct numeric data use, without the need for employing initial discretization. On one hand it simplifies the process of data gathering, on the other, improves readability and interpretation of the created rules. In such a situation, the Expert System user previews parameter values included in rule reasoning. Additional advantage of MODLEM algorithm, in spite of its slightly lower classification effectiveness, is low percentage of incorrectly classified examples (in case of initially non-digitalized data). Doubtful examples are then dropped without any classification.

SYSTEM CONCEPT

The following general assumptions were adopted in relation to the manner of operation of Expert Diagnostic System for ship engine:

1. System user (ship mechanic) feeds data into a computer in form of answers to system-generated questions.
2. System may also use data from ship database automatically.
3. System generates diagnosis statements on engine qualification to the class of particular conditions.

Basic role of Expert System is to produce statement diagnosis while taking into account input data (fed directly by user or taken automatically from database).

Adopted architecture of the system is of module type. This enables, among other things, easy system updating by adding new elements and making multiple configurations. The structure of the system is presented in Figure 1.

The most important detail of the whole system is Conclusion Module. It is responsible for the reasoning process and choosing relevant diagnosis. Conclusion Module and Interface Control use CLIPS language. CLIPS enables building basic system elements in homogenous environment. Conclusion Machine, Interface Control and Knowledge Database perform their duties in CLIPS environment.

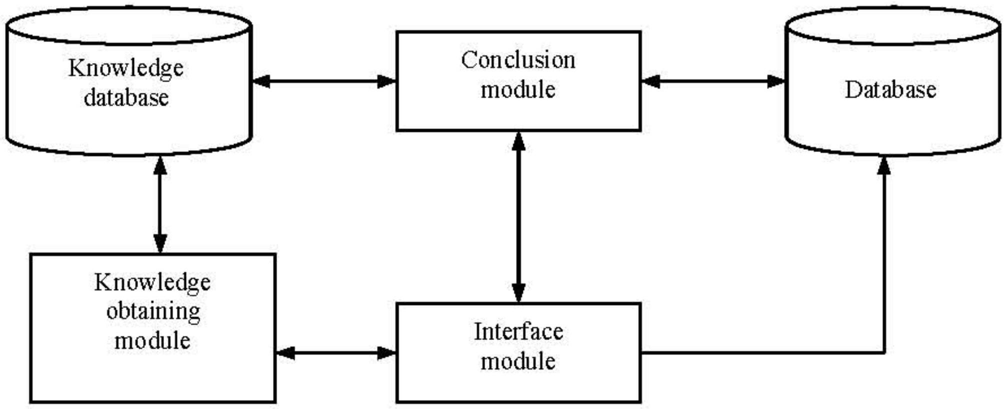

Fig. 1. The general structure of Expert System

Source: own study.

SUMMARY

Complex diagnostic systems for marine diesel engine diagnosis face limited application in ships, particularly due to their high cost. Ship engines are fitted with assorted indicators and measurement tools enabling control of many operational parameters, as well as, storing such measurements in databases. Technical condition verdict is however still the responsibility of the engine operator, and here comes the room for IT systems, which could facilitate such processes.

The expert system application may substantially enhance abilities of monitoring systems presently existent in power rooms, in respect of ship engine diagnosis. Such system enables saving valuable, operational knowledge for later use. Additional advantage, represents the opportunity of automatic collection of diagnostic information with machine learning methods. The usefulness of such methods for creation of diagnostic rules was proved on the basis of examples stored in database.

The expert system enables integration within a single frame of both information collected from experts and automatically collected one. A doubtless advantage of expert system is the opportunity of updating and developing the content recorded in the database. Due to this feature, the effectiveness of the system may grow during engine operation and facilitate gaining new experience.

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ZASTOSOWANIE SYSTEMU EKSPERCKIEGO DO DIAGNOZY WYSOKOPRĘŻNYCH SILNIKÓW OKRĘTOWYCH

STRESZCZENIE

Artykuł przedstawia system diagnostyczny okrętowego silnika wysokoprężnego oparty na modelu systemu eksperckiego. Przeprowadzono badania odpowiednia dla pozyskania informacji o tym systemie, stworzono zestaw danych oraz zaproponowano struktury ogólne systemu eksperckiego. Zidentyfikowano również podstawowe źródła informacji, które mogą być wykorzystane do budowy zestawu danych wiedzy. Podstawowa wiedza odnosząca się do diagnostyki silników wysokoprężnych została wzięta z eksperckich i diagnostycznych baz danych. Wykorzystano kwestionariusz papierowy w celu uzyskania wiedzy od ekspertów. Uzyskano podstawowe informacje odnoszącą się do eksploatacji silników okrętowych. Zastosowano algorytmy rule induction do uzyskania informacji z bazy danych. Podczas eksperymentu sprawność algorytmów induction LEM została porównana z nowymi algorytmami MODLEM i EXPLORE. Dane szkoleniowe i testowe zostały uzyskane z eksperymentu na silniku okrętowym Sulzer 3AL 25/30.

Słowa kluczowe:

diagnostyka techniczna, system ekspercki, wysokoprężne silniki okrętowe.