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EXAMPLES OF AN EXPERT SYSTEM IN THE ESTIMATION OF THE QUALITY OF LUBRICANTS

Denijal Sprecic, Elis Sprecic, Jože Vižintin and Alojz Sluga

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1. Introduction

System of Automation of Experiments (SAE) constitutes a group of various units (sub-systems), connected into one structural and functional entirety capable of performing certain functions and solving the set tasks. The characteristics of SAE should be the flexibility and the easy hardware and software possibility of further expansion (development) of the system and of the system connecting with other experimental systems on the module principle. Each SAE should satisfy certain metrological, technical, kibernetic and economic requirements they are part of: high productivity and reliability of the system, easy usage (exploitation) of the systems in terms of hardware and software, the necessary flexibility and the universality of the hardware part of the system, the lowest possible price of the system, etc. That is where the requirements (of contemporary experiments) result from: very fast, and in addition also the most frequent, very precise identification of the state, behaviour and reaction of the analysed object during the course of the experiment running. To the very quick changes in the investigated phenomena the following significant issues should be added, such as are:

- in contemporary experiments, a great number of values is, almost regularly, measured simultaneously,
- measurements results are obtained in abundance within a relatively short period of time, and
- it is not a rare case that the results are quickly and precisely mathematically treated.

Consequently, it is rarely that all the above mentioned tasks can be successfully resolved by using a classical experimental technique. They are, therefore, solved by means of new systems of automation of the experimental analysing (within the experimental method framework) or by means of the System of Automation of Experiments (SAE) into which the expert system based upon knowledge, that is the hybrid expert system, can be integrated.

2. SAE in the Analysis of Lubricants

Recently the development of SAE has been so fast that they now make one of the dominating classes of the measurement of systems (information measurement systems) in engineering, particularly in technical and scientific researches. In the Figure 1 is illustrated a concrete example of SAE referring to the system of automation of analysis of lubricants. This is a system oriented to a specific class of experiments. A typical function of the system is the statistical treatment of experimental results, a series of experiments and analyses, assessment and interpretation of the experimental formation, creation of the output information in a form that is suitable for subsequent usage. The system operates in a regime of multiple programs with a fixed number of tasks and the system functioning process, respectively, is described using a model of mass servicing with ordinary (non-accelerated) servicing course.

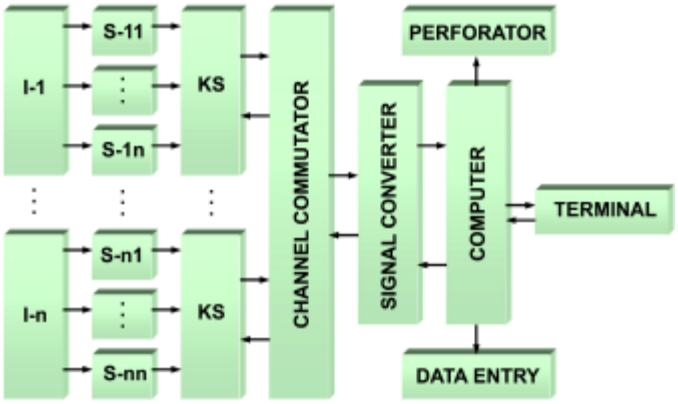


Figure 1. Scheme of the system of automation of experiments structure for the analysis of the quality of lubricants

The individual units (modules) of the system illustrated in the Figure 1 constitute: instruments used to analyse the quality of lubricants (I), sensors for the identification of the characteristics of lubricants (S) and commutators of sensors (KS). The link between the analysis objects, the control unit and the experimental (measurement) system is achieved through aggregate modules by means of which analogue and discrete signals are introduced into a system or led out of it.

3. Integration of the Analysis of the Quality of Lubricants and of the Maintenance System Control

Several phases can be established in the development of an expert system based upon the principle of the integration of analyses of the quality of lubricants and of the maintenance system control, one of the phases being illustrated in the Figure 2.

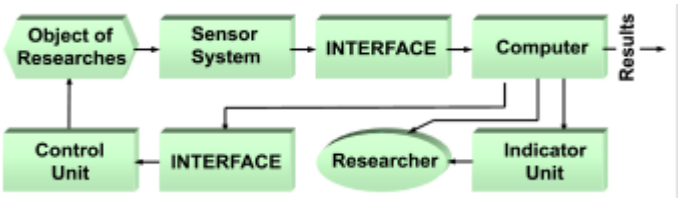
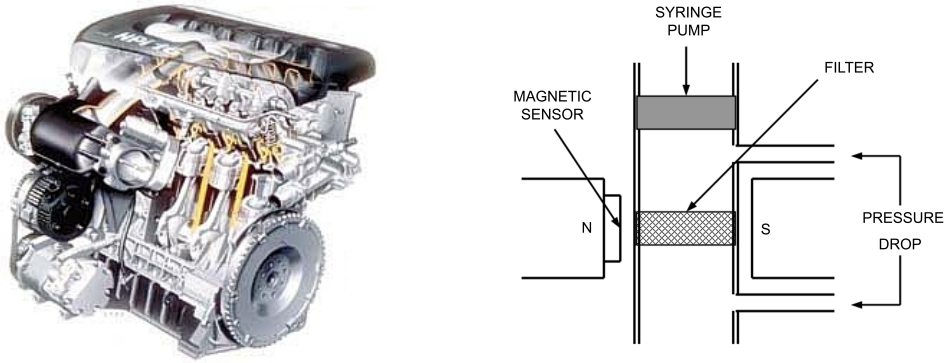


Figure 2. Phase of the integration of the analysis of the quality of lubricants and of the maintenance system control

On-site analysis of the lubricating oil is one of the essential elements of the reliability of the mechanical system as a whole.



a) **b)**

Figure 3. a) Observed mechanical system b) Structure of the system for the on-site lubricating oil analysis VIP

In this the integration of conclusions on the system reliability with the lubricating as a factor of the maintenance system control, is necessary. The benefits resulting from closely integrated reliability with the maintenance system control are multiple in terms of timely identification of the state of lubricants the quality of which conditions a higher reliability and readiness of the observed mechanical system, but simultaneously also shows the state of an worn out condition of the given system.There are several successful methods for the on-site lubricating oil analysis during its direct usage. The on-site instruments determine the state of the machines and of the lubricating oil in their direct usage. The application of instruments based upon the principle of filters is frequent, in which case are obtained samples which are further used for the laboratory analysis. The results obtained using the on-site methods are suitable because they are actual in terms of reaching the individual real-time conclusions. In the Figure 3b. is illustrated VIP instrument for the lubricating oil analysis by means of which it is possible to obtain the results on the wear of the machine, lubricating oil contamination with metal particles and on the viscosity. In addition to the instrument illustrated in the Figure 3b., a more complicated configuration with the instruments within the framework of the laboratory for the lubricants analysis is used for a more detailed determination of the lubricating oil condition.

3.1 Configuration of the Laboratory for the Analysis of Lubricants

The laboratory for the analysis of lubricants illustrated in the Figure 4. is not associated with the samples and analyses of special kinds that it can carry out, unlike some laboratories which are specialised for experiments of certain kinds and which are oriented to the samples of a certain kind, for which reason the instruments of modified designs are used.

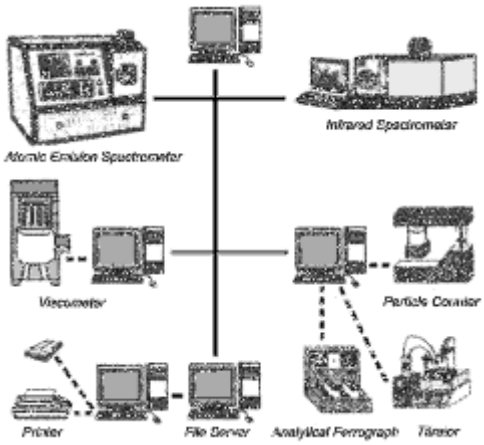


Figure 4. Laboratory for the analysis of lubricants

Within the framework of the above mentioned laboratory the lubricating oil contamination and the additives in the lubricating oil are determined, then the physical and chemical characteristics of this lubricating oil are determined, as well as its viscosity, total acid number (TAN), total base number (TBN), water content, the detection of particles and the values. The laboratory is equipped also with the configuration for the evolution and the presentation of data.

4. The Link between Expert Systems and the Artificial Intelligence

4.1 Knowledge Based Expert Systems

Given all the principled differences existing between the expert systems and the neural networks, it is possible to say that they constitute two close models for the treatment of information, which in turn in a concrete example, represent results obtained through the laboratory analysis of lubricating oils. Namely, both models for the solution of problems use, as their basic component, knowledge and constitute the so-called knowledge based systems. The definitions of the knowledge based system in literature differ, however, the observation that these are computer programs which collect, memorise

and use knowledge from a certain field for specific purposes is common to all of them. The basic structure consists of the knowledge base which saves knowledge and of the machine for inference which reasons based upon this knowledge (Figure 5).

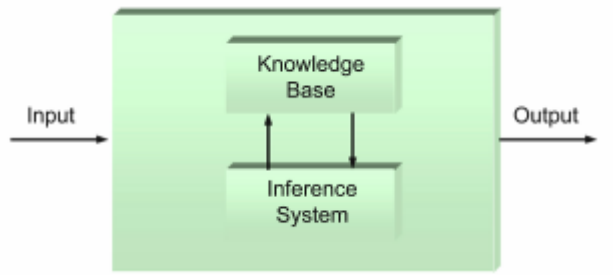


Figure 5. The flow of information in an intelligent system

The strength of such a system lies primarily in the knowledge it possesses, and to a lesser extent, in the way of inferring. The basic difference between expert systems and neural networks is in the way of presenting (memorising) knowledge from a certain subject field. While in expert systems different ways of symbolic presentation (production systems, semantic nets, networks, logic of predicates), neural networks use brain analogy by means of which intelligence-knowledge is presented through a group of weights of links between a greater number of process elements, each of them performing simple calculations. This difference results also in different efficiencies of the systems based upon knowledge in individual situations. For example, the symbolic systems are thus understandable and can explain and justify their conclusions, while the neural networks better infer in the case of unreliable or incomplete items of information and owing to their structure links they have the capability of learning through examples. A concrete case of application of neural network and adaptive neuro-fuzzy system of inference is given on the example of the determination of the quality of the lubricating oil type INA LOKOMOL HS-40 where are isolated in the Table 1. the characteristics of the lubricants containing chemical elements, the percentage contents of which in the lubricating oil were obtained by means of the experimental, that is, the laboratory methods of analysing lubricating oils (Figure 4).

Table 1. Characteristics of lubricants and chemical elements in a lubricant

Characteristics of lubricants	Chemical Elements %				
Viscosity (100°C) [mm^2/s]	Ca	P	Zn	Fe	Cr
Flash Point PM [°C]	Mo	Sn	Pb	Cu	Na
TBN [mgKOH/g]	Mg	B	Al	Ag	Si

The neural network structure was generated based upon input and output values defined in such a way that viscosity (100 °C) [mm^2/s] - input1, flash point-PM [°C] - input2 and TBN [mgKOH/g] - input3 were taken for input variables, and at the output the percentage content of chemical elements-output14 presented in Table 1., was required.

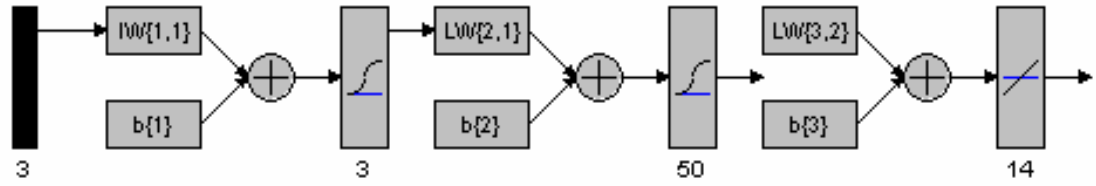


Figure 6. Structure of neural network used in the lubricating oil quality assessment

The combination of the neural network and of the searching for a rule is an empirically valid method for obtaining expert rules. In a concrete example of the neural network application to the lubricating

oil quality assessment a high degree of precision of the generated model operation (Figure 6) was achieved. According to this model the percentage contents of chemical elements present in the lubricating oil can be obtained with high degree of precision for further determined values of input variables by means of one of classical methods of analysing the lubricating oils. As can be seen from the stated neural network structure a functional dependence between the input variable and 14 outputs, which are actually percentage contents of the chemical elements in the analysed lubricating oil, was set.

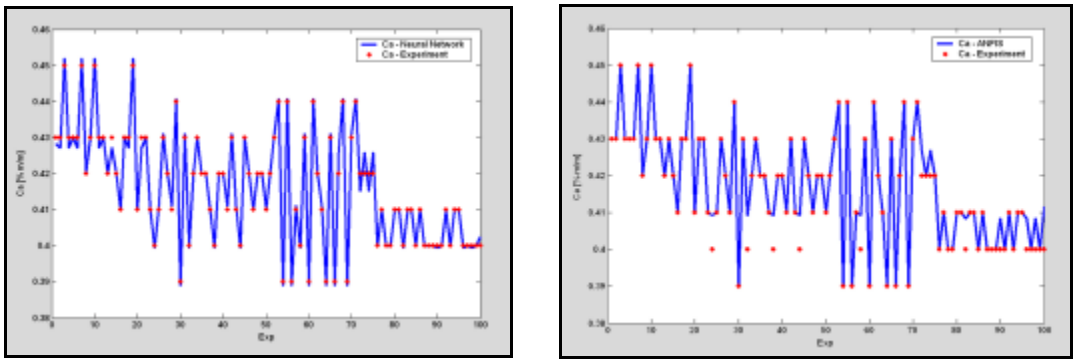


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Figure 7. Precision of operation a) of neural network b) of ANFIS model on the example of one output variable, that is of the Ca[% m/m] content

In terms of structure, the only restriction of net-like configurations is in the fact that they should be trained with already existing data prior to their application, if complex asynchronous model is to be used. Due to this minimal restriction adaptive networks are used which can be applied to several different problems: modelling, inference, signal processing and control. The structure designated as ANFIS, with the meaning of adaptive networks, based upon fuzzy system of inference, exists in two forms: Sugeno and Tsukamoto fuzzy models. Thus the Sugeno fuzzy model is used for the determination of the observed lubricating oil quality.

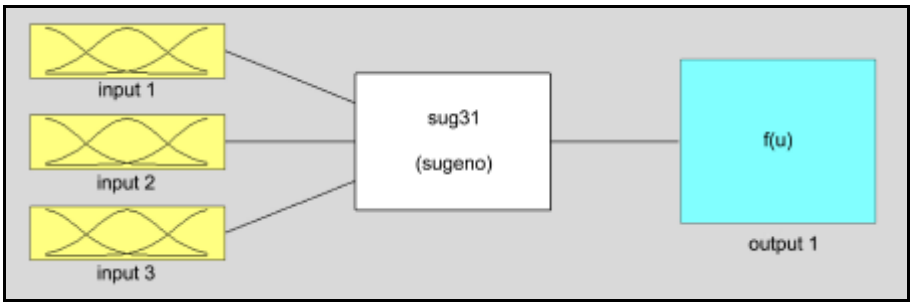

Figure 8. Simplified structure of ANFIS model

In the set ANFIS model, the functional dependence of one output value (of the content Ca [% m/m]-output1) on three input variables (viscosity (100°C) [mm^2/s] - input1, flash point-PM [°C] - input2 and TBN [mgKOH/g] - input3), is given unlike the previously presented neural network. The application of the ANFIS model of inference and the searching for rules is another empirically valid method for obtaining expert rules. It is also efficient for the data given in a concrete example for the lubricating oil quality assessment as well. Since this is an adaptive neuro-fuzzy system of inference, its advantage lies in the fact that it makes possible the change in the difficulty of the rule in the created model. For the given model 16 rules were generated, being possible for their number to be increased and decreased, respectively. In this way it is possible to exert a direct influence upon the degree of accuracy and validity of the results obtained from the model. In the concrete example of the ANFIS module usage to assess the lubricating oil quality a high degree of performance of the generated models, the number of which is defined by the number of the output values, was also achieved.

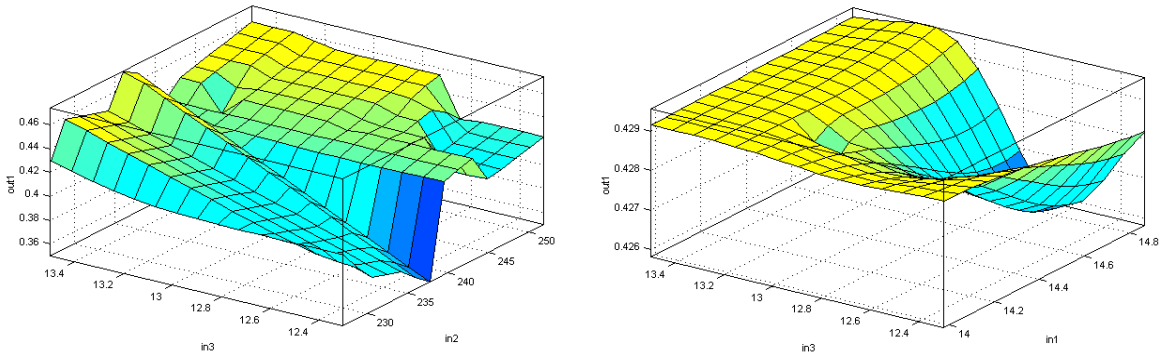

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Figure 9. Three-dimensional presentation of the change in the output variable (the content Ca [% m/m] in the lubricating oil) depending on the input variables a) TBN [mgKOH/g] and the flash point-PM [°C] b) viscosity (100 °C) [mm^2/s] and the flash point-PM [°C]

According to these models it is possible to obtain the percentage content of the chemical elements present in the lubricating oil for the concrete values of the input variables the same as also for the neural network model. In order to be able to make a good quality usage of the artificial intelligence when determining the quality of the lubricating oil which uses the neural networks and the adaptive neuro-fuzzy modules of inference, respectively, it is necessary to establish previously the experimental values both for the new lubricating oils and for the condition when the observed lubricating oil is no longer suitable to be used. The number of the experimentally obtained values which are used in the training procedure exerts direct influence upon the accuracy of the operation of the neural network and of the adaptive neuro-fuzzy module of inference.

Acknowledgement

The precision of the scientific knowledge has a very wide significance for the acceleration of a science development rate and for the increase of the value of its results. Every new means of observation, running of experiments, treatment of results and others, enable the expansion of researches to some new fields, and this in turn, exerts a significant influence upon the changing and improvement of all the elements of a scientific activity. The application of statistical methods and the generalisation of the investigated phenomena are made possible by a great number of data. The improvement of certain types of researches also influences the precision. Above all, this refers to the field in which experiments can be carried out using the instruments which are getting more and more sophisticated (perfect), so that new knowledge will be more definite, more reliable and more precise. The possibility of using the system of automation of experiments, the application of expert systems and of the artificial intelligence are sure to contribute to this, and this has, as a matter of fact, been done in the concrete example of determining the lubricant quality.

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Prof. Dr. Denijal Sprecic
University of Tuzla
Faculty of Mechanical Engineering
Univerzitetska 8, 75000 Tuzla, Bosnia &Herzegovina
Tel./Fax: +387 35 283 304
E-mail: esprecic@bih.net.ba