TUNING OF BELIEF NETWORK-BASED DIAGNOSTIC MODEL

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Summary

This paper presents a multi-stage diagnostic Belief Network Based Model (BNBM). Proposed model allows for application of acquired knowledge from data training, domain experts and domain literature. This feature is its special advantage. A general model structure, selected issues with its identification and application were shown as well. Described BNBM model consists of three stages: preliminary data processing, equalization and balance of additional variables and belief network. Tuning of BNBM model with using memetic algorithm as global optimization method with local optimization was proposed.

Keywords: belief network, model tuning, diagnostic model, memetic algorithm.

STROJENIE MODELU DIAGNOSTYCZNEGO OPARTEGO NA SIECI PRZEKONAŃ

Streszczenie

W artykule opisano wielostopniowy model diagnostyczny bazujący na sieci przekonań. Przedstawiono ogólną strukturę modelu oraz omówiono problemy związane z jego identyfikacją oraz strojeniem. Szczególną zaletą proponowanego modelu jest to, że pozwala on na stosowanie wiedzy pozyskanej zarówno z danych uczących jak i artykułowanej bezpośrednio przez specjalistów i literaturę rozpatrywanej dziedziny. Opisany model diagnostyczny składa się ze stopnia wstępnego przetwarzania, stopnia uzgadniania oraz stopnia w postaci sieci przekonań. Dla przyjętej ogólnej postaci modelu omówiono procedurę strojenia z użyciem algorytmu genetycznego. Z uwagi na wady i zalety tego algorytmu dokonano modyfikacji procedury strojenia poprzez zastosowanie algorytmu memetycznego. Określono kierunki dalszych prac badawczych.

Słowa kluczowe: sieć przekonań, strojenie modelu, model diagnostyczny, algorytm memetyczny.

1. INTRODUCTION

Wide range access to high computer technology bring a rapid growth of methods of condition monitoring. Many efforts to make diagnostic systems more efficient, which allow to early detection and isolation, fault tolerant control, state prediction ect. are still in development. One of the example is an intelligent diagnostics and process control system DiaSter [11], which combine a lot of methods from process variable selection to visualization of diagnostic results. An integral part of DiaSter system is a plugin for diagnostics with using a belief networks and multi-aspect models [3]. This model allows to apply model-based and symptom diagnostic commonly.

1.1. Model-based diagnostics

The essence of model-based diagnostics is the recognition of state class for an observed object by the analysis of generated residuals between measured values of output signals y and calculated output of model y_M. The model have to be appropriate tuned to the observed object. Such model or set of models of each state class can be used during model-based diagnostic. The main condition of using model based diagnostics is an assumption that simulation inputs and observed inputs are the same. [4].

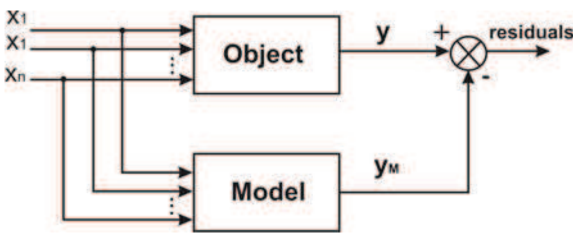

Fig. 1. Model-based diagnostics

1.2. Symptom diagnostics

Considering symptom diagnostics problems, we assume that effect of state changes of object are correlated with arising of state symptoms, which in turn indicate these faults [1]. In a case of symptom diagnostics, the main assumption is to use domain expert knowledge which can be helpful in selection of relevant symptoms. Methods of collection, representation and notation of state-symptom relation have an essential meaning. There are many methods for gathering of state-symptom relations. In general, for symptom diagnostics, data can be collected from domain experts, passive diagnostic experiments and active diagnostic experiments.

2. BELIEF NETWORK-BASED MODEL

Considering advantages of symptom diagnostics and model-based diagnostics, a belief network-based diagnostic model (BNBM) which combine above features was proposed [3]. Let's consider model BNBM, where values of inputs and outputs are vectors x_D and y_D. Model inputs include: observed values of features, design features, parameters of operation conditions of an object. The model outputs are results of diagnostic process which can be represented as belief rate of class of state of observed object.

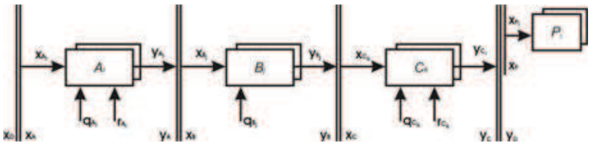

Fig. 2. Belief Network-Based Model

Multi-stage BNBM model (Fig.2.), which transforms input data x_D to output data y_D, consist of stages A_i, B_i, C_i [3], where:

- first stage A_i is a block of pre-processing of data,
- second stage B_i, which consist of blocks for equalization and balance of additional values,
- third stage C_i, which consist of a set of belief network.

Moreover, for application of BNBM model, an external module P_l for visualization of results was added.

Main task of first stage is a reduction of the number of considered features of diagnostic signals which can be obtained by: data normalization, multidimensional scaling and more complex processes of transformation input data. Transformation process can be also done with the use of a set of *One Class Classifiers* which can be interpret as a membership functions of fuzzy sets.

Equalization and balance blocks are used to incorporate constraint equations which come from domain knowledge of observed object. Lack of domain knowledge cause omitting of second stage by moving inputs to outputs without changes.

Third stage is belief networks set [10], which realize tasks coming from symptom diagnostics where knowledge is represented by descriptions state-symptom relations. Convenient representation form of approximate knowledge is a statement.

The statement is an assertion about the recognition of observed facts or assertion representing a given opinion. A statement s can be written down in the form of the pair::

$$s =< c; b > \quad (1)$$

where:

c - the statement content, and thus, e.g., an opinion on that a given object is entitled to have a given attribute, whose value is established;

b – a (logical) value of the statement of [0,1]. It is defined as the truth factor or degree of belief and concerns the content of the statement.

Bayesian Network identification is a complex process. The network structures can be defined with the use of machine learning techniques or cooperation of domain experts. The second difficult task is defining of Condition Probability Tables for each node of the network. It can be done trough identification and tuning which is directly based on the knowledge of a domain expert, intuition of knowledge engineer (a priori). Another way is to perform the process automatically with the use of learning data sets. Quality of learning is dependent on a size of data set and its quality. Some learning algorithms reduce the negative influence on small learning data sets by consideration of non-complete statements in a node. A part of data is introduced to the system manually and the rest of elements of the set can be defined in automatically way. Obtained model can be further tuned.

Statements vector of considered state classes is the result of third stage (1). The specific structure of the BNBM model allows to link selected outputs of previous blocks with the inputs of next blocks.

Each stage of BNBM (Fig.2) consists of configuration parameters. There are parameters which can not be changed $\underline{q}$ and parameters to be tuned $\underline{r}$ depending on the needs.

3. IDENTIFICATION AND TUNING OF BNBM

Identification of Belief Network-Based Model is a complex process. It requires of carefully analysis of considered problem and can be done in two steps:

- build of complete initial version of model,
- improving and tuning of model during iterative process.

It is necessary to collect and prepare data training for building the initial version of model.

3.1. Model identification

Iterative identification process of BNBM consists of the following steps:
- Defining of model input and output set, statement contents and global structure.
- Analysis of accessible model and additional variables.
- Building of equalization and balance blocks based on knowledge.
- Independent identification of each classifier on the base of prepared training data.
- Independent identification of bayesian network on the base of prepared and transformed by block A_i training data.
- Model testing.

Identified initial version of BNBM should be improved.

2.2. Tuning of BNBM

Tuning of proposed multi-stage heuristic model is difficult and complex task and requires application of method for global optimization. Genetic Algorithms meet this criteria [8]. GA are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology used in computing to find exact or approximate solutions to optimization and search problem. Typical GA can be written as follows:

```
procedure Genetic_Algorithm
{   t ← 0 ;
    P(t) ← initialization( ) ;
    while(not termination_condition)
    {   t ← t + 1 ;
        R(t) ← evaluation_and_selection( P(t − 1) ) ;
        D(t) ← reproduction( R(t) ) ;
        N(t) ← evaluation_and_selection( P(t − 1) ) ;
        P(t) ← ( P(t − 1) + D(t) − N(t) ) ;
    }
}
```

An advantage of genetic algorithm is possibility to find a global solution. Moreover, a genetic algorithm shows high resistance for extreme of criteria function. In spite of above advantages of GA for global optimization, its provide to getting individuals with limited solution cause of optimization individuals features of population. Another disadvantage of genetic algorithms is lack of individuals learning. To this end, genetic algorithm is improved by additional operations to modify elite individuals for improve themselves during the evolutionary cycle [12]. This kind of synergy of evolutionary and local improvement procedures is called Memetic Algorithm (MA). Typical procedure of MA can be written as follows:

```
procedure Memetic_Algorithm
{   t ← 0 ;
    P(t) ← initialization( ) ;
    while(not termination_condition)
    {   t ← t + 1 ;
        R(t) ← evaluation_and_selection( P(t − 1) ) ;
        D(t) ← reproduction( R(t) ) ;
        N(t) ← evaluation_and_selection( P(t − 1) ) ;
        P(t) ← ( P(t − 1) + D(t) − N(t) );
        E(t) ← evaluation_and_selection( P(t) ) ;
        E(t) ← local_optimization( E(t) );
    }
}
```

Tuning of Belief Network-Based Model can be done by:
- independent improvement of stage A_i and stage C_i,
- simultaneous tuning of both considered stages A_i and C_i.

Configuration parameters $\underline{r}$ of stages A_i and C_i for considered model can be tuned (Fig. 1). They may be interpret as equivalent of genes and memes of memetic algorithm. It requires a special kind of codification of information.

The set of tuned configuration parameters for blocks of first stage may include centers location of membership function of one class classifier. Another important tuned parameter of this stage is the number of class of considered additional values. Optimal defining above parameter require detailed analysis of changes range of additional values. Small number of class of additional values lead to incorrect or weak results. However excess of class numbers increase time of calculation during the identification and tuning process.

Tuned parameters of belief network are Conditional Probability Tables (CPT) defined during identification process. Belief network tuning can be based on modification of Conditional Probability Tables for all nodes and than modification of Conditional Probability Tables for selected nodes. Expectation-maximization algorithm (EM) can be applied for tuning of CPT, where tuned parameters are number of iterations and learning error. Moreover, belief network structure can be tuned by inserting of additional weight node to clear-cut for point at searching solution.

Another difficult task of tuning process is defining of fitness function of memetic algorithm for selection of individuals and for local optimization of elite individuals. There are no clear-cut recipes for definition of feet function because it depends on the considered problem.

4. SUMMARY

Research connected with the development of identification methods and tuning of Belief Network-Based Model is still in progress. Implementation in C++ of described concept as plugin of diagnostic system framework was done. At present, a practical application and implementation of model for DiaSter system is under work.

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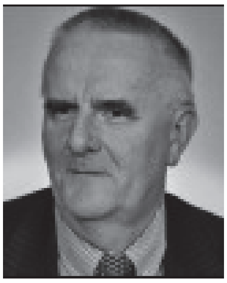

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