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Reliability of comparative-threshold diagnostic processes[1]

K e y w o r d s

The diagnosing, the reliability of the diagnosis, the uncertainty of the symptom, the comparation of syndromes, the threshold measuring-system.

S ł o w a k l u c z o w e

Diagnozowanie, niezawodność diagnozy, niepewność symptomu, komparacja syndromów, progowy układ pomiarowy.

S u m m a r y

Scientific works carried out in the years 2006–2011 by the team of Professor Lesław Będkowski come down to the following two main topics:
– reliability of diagnoses based on uncertain state symptoms;
– diagnostic and supervising methods and procedures resistant to disturbance.

The onsiderations, analyses and studies carried out resulted in publications, which may be grouped in a few subject-correlated themes:

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[1] The authors wish to dedicate the paper to the memory of Professor Lesław Będkowski, because it covers a synthetic review of the publications inspired by Professor Będkowski in the last 5 years of his life, i.e. 2006–2011.

– diagnostics with multi-level comparison of uncertain symptoms and syndromes of the object state;
– uncertainty in the diagnostic and supervising processes;
– threshold measuring in diagnostic systems;
– research of the characteristics of comparative-threshold supervision method in the aspect of adaptation to the nature of the diagnostic signal;
– comparative-threshold diagnostics in the information transmission systems.

The basic elements of the above issues and the research results conclusions are the subject of this paper.

Introduction

Scientific works carried out in the years 2006–2011 by the team of Professor Lesław Będkowski come down to the following two main topics:
– The reliability of diagnoses based on uncertain state symptoms, and
– Diagnostic and supervising methods and procedures resistant to disturbance.

The considerations, analyses, and studies carried out resulted in publications, which may be grouped in a few subject-correlated themes:
– Diagnostics with multi-level comparison of uncertain symptoms and syndromes of the object state [1, 2, 3];
– Uncertainty in the diagnostic and supervising processes [3, 4, 5, 6, 16];
– Threshold measuring in diagnostic systems [7, 8, 9, 10, 12, 13, 15, 16, 17];
– Research of the characteristics of the comparative-threshold supervision method in the aspect of adaptation to the nature of the diagnostic signal [12, 15, 16, 17]; and,
– Comparative-threshold diagnostics in the information transmission systems [6, 8, 11, 13, 14, 18].

The basic elements of the above issues and the research results conclusions are the subject of this paper.

Diagnostics with the use of multi-level comparisons of uncertain symptoms and syndromes of the object state [1, 2, 3]

The publications are devoted to the reliability of diagnoses formulated on the basis of uncertain (e.g. owing to the diagnostic process disturbance) symptoms and syndromes of the object state. The publications include a description of the diagnostic method enabling the arrival at sufficiently reliable diagnoses due to repeated testing and comparison of the received symptoms and syndromes. Several rules facilitating the selection of the correct diagnosis are described, and assessment indicators for the diagnostic process reliability are defined.

The essence of the diagnostic procedure for a multi-module object is presented in Figure 1.

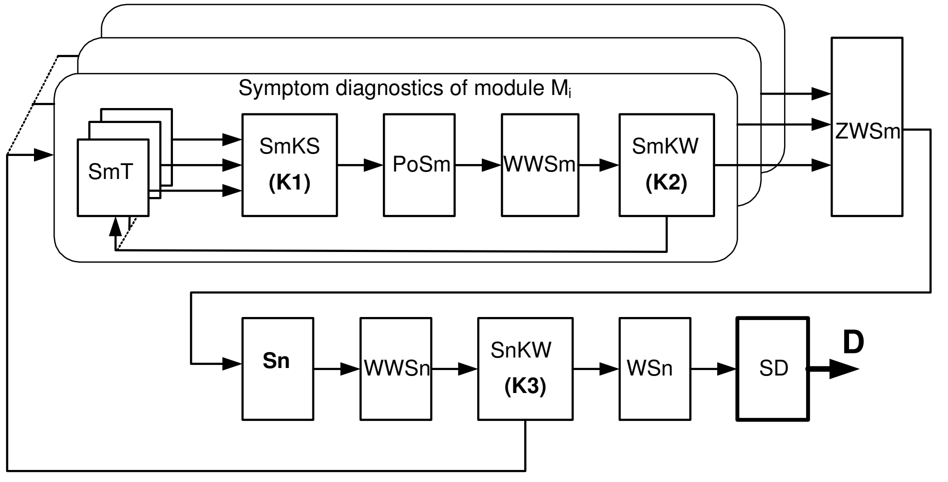

Fig. 1. Algorithm of the comparative diagnostic procedure.
Identification: SmT – symptom module testing; SmKS – symptom segregation comparison; PoSm – symptoms subsets; WWSm – symptoms value determination; SmKW – symptom value comparison; ZWSm – selected symptoms set; Sn – state symptom; WWSn – syndrome value determination; SnKW – syndrome value comparison; WSn – selected syndrome; SD – synthetic diagnosis; D – diagnosis
Rys. 1. Algorytm komparacyjnej procedury diagnostycznej
Oznaczenia: SmT – symptomowe testowanie modułu; SmKS – symptomowa komparacja segregująca; PoSm – podzbiory symptomów; WWSm – wyznaczanie wartości symptomów; SmKW – symptomowa komparacja wartościująca; ZWSm – zbiór wybranych symptomów; Sn – syndrom stanu; WWSn – wyznaczanie wartości syndromu; SnKW – syndromowa komparacja wartościująca; WSn – wybrany syndrom; SD – synteza diagnozy; D – diagnoza

The main elements of the subject-matter procedure are the following comparative operations:

– Segregation comparison (K1), which segregates the received symptoms into subsets of identical form with simultaneous determination of their quantity;
– Value comparison (K2), which sets out the value of the particular symptoms subsets and identifies – for each object module diagnosed – the subset of the highest value symptoms; and,
– Value comparison (K3), which serves the determination of particular symptom values and the selection of the highest value syndrome.

In this paper, it has been assumed that the measure of a symptom (and syndrome) value is the value of the probability of the symptom (syndrome) reality.

This method is mainly useful when (for various reasons) it is advisable to apply diagnostic inference at the level of complete syndromes or when the number of the possible object states is large and there are problems with strict a priori definition of all of the possible object states. Moreover, the method may be applied if there are different requirements for the limit values of symptoms.

Important elements of the discussed publications are useful expressions for the determination of the values of state symptoms and syndromes, as well as proposals of some decision-making rules with regard to the necessary number of symptoms subsets and the required credibility (and reliability) of diagnoses.

Conclusion

On the basis of a diagnostic system simulation model, verification of the described diagnostic procedure with "two-level comparison" (i.e. on the level of symptoms and syndromes) confirms the useful value of the method and, in particular, supports the conviction of the authors of the following conclusions:

- A method with adequately chosen rules of symptoms, syndrome and diagnosis selection is suitable for diagnosing objects that may be subjected to strong disturbance (even if the diagnostic systems are subjected to a similar disturbance).
- The method may be applied even if *a priori* probabilities of the tested object modules states are not known.
- The described procedure does not require knowledge of the nature of disturbances affecting the diagnostic system, i.e. the type of the disturbance distribution.

Uncertainty in diagnostic and supervision processes [3, 4, 5, 6, 16]

The publications refer to the issue of credibility (and reliability) of the diagnoses formulated in the diagnostic and supervision processes of the objects exposed to major disturbances of both the functional and diagnostic signals. The authors propose a diagnostic method that provides and means to credible diagnoses, using multiple testing and comparison of the received syndromes. The publications discuss one-channel and two-channel sequential supervision in the case of a considerable uncertainty of the object state symptoms (and syndromes). Methods of final diagnosis synthesis based on an adequate number of the diagnostic sessions held are characterised.

The essence of credible diagnostics on the basis of uncertain state syndromes [3] is explained in Figure 2.

In practice, it rarely happens that the probability of one of the possible states equals one, i.e. that the state is absolutely sure. Generally, there is an uncertainty expressed in the fact that probability close to one may be assigned only to one state at most; whereas, the probabilities of the other states are close to zero. In the case of the uncertainty of symptoms, the distribution of the state probabilities should be analysed to formulate the basis for diagnosis.

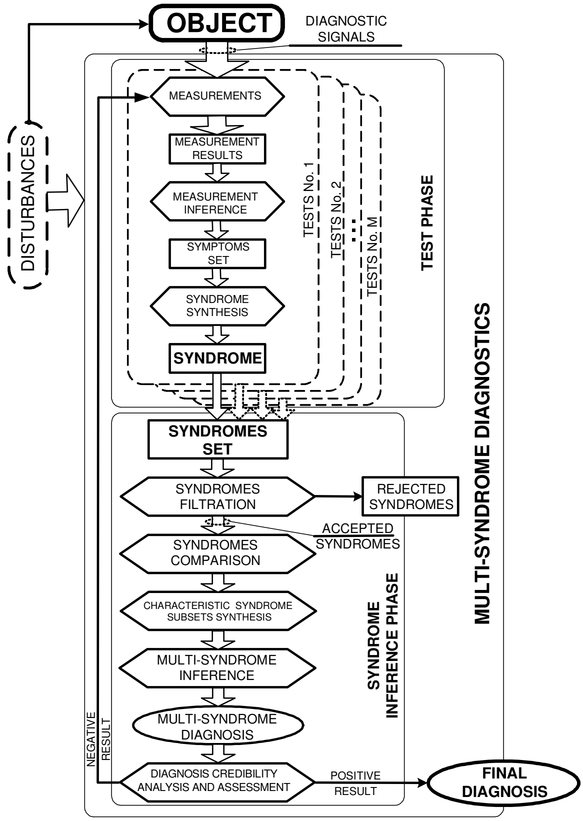

Fig. 2. General algorithm of the diagnostic procedure in the case of uncertain syndromes
Rys. 2. Ogólny algorytm procedury diagnozowania w przypadku niepewnych syndromów

If the dominating state probability value is too low or the analyst does not believe the inferred diagnosis due to other reasons, tests are usually repeated. Repeated evidence of the same syndrome may confirm the credibility of the diagnosis. Repeating tests and arriving at an adequately numerous set of syndromes is equivalent to receiving **information overload**.

This contributes to extending the time required for diagnosis; therefore, information overload requires the possession of **time redundancy**.

We observe that the results of tests, measurement inference and symptom inference may be uncertain. Therefore, one-time testing and the received syndrome may be uncertain, which means that **one-syndrome diagnosis may be uncertain**.

In such cases, multiple tests must be applied, and the **diagnosis synthesis must be based on multi-syndrome inference**.

Paper [3] describes the dependence that enables the determination of the probability of a positive and a negative syndrome authenticity, as well as the probability of the diagnosis authenticity as a function of the number of the state syndromes registered.

The essence of sequential supervision of fixed or variable programmes using one-channel or two-channel supervision process [4, 5] is explained in Figures 3 and 4.

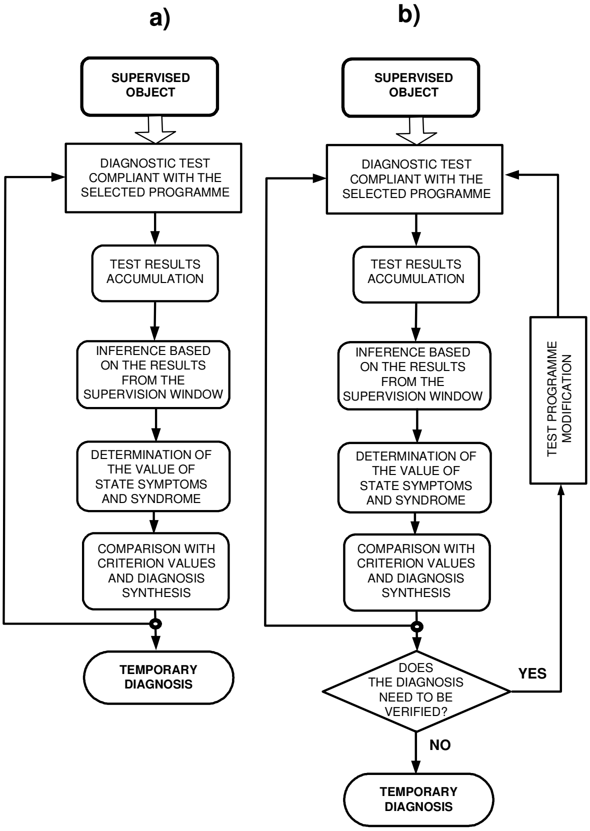

Fig. 3. Algorithm of one-channel supervision process: a) fixed-programme supervision, b) variable-programme supervision

Rys. 3. Algorytm procesu dozorowania jednokanałowego: a) dozorowanie stałoprogramowe, b) dozorowanie zmiennoprogramowe

It is worth mentioning that supervision is a diagnostic process performed simultaneously with the process of object use. The overriding objective of supervision is to observe the trajectory of object stage changes in real time. In that aspect, the "time of supervision delay" including the time of credible state symptoms and syndrome identification becomes very important.

The solutions proposed in the discussed papers focus on the minimisation of time elapsing from the moment of a significant state change occurrence to the moment of information generation (diagnosis), if such change is present.

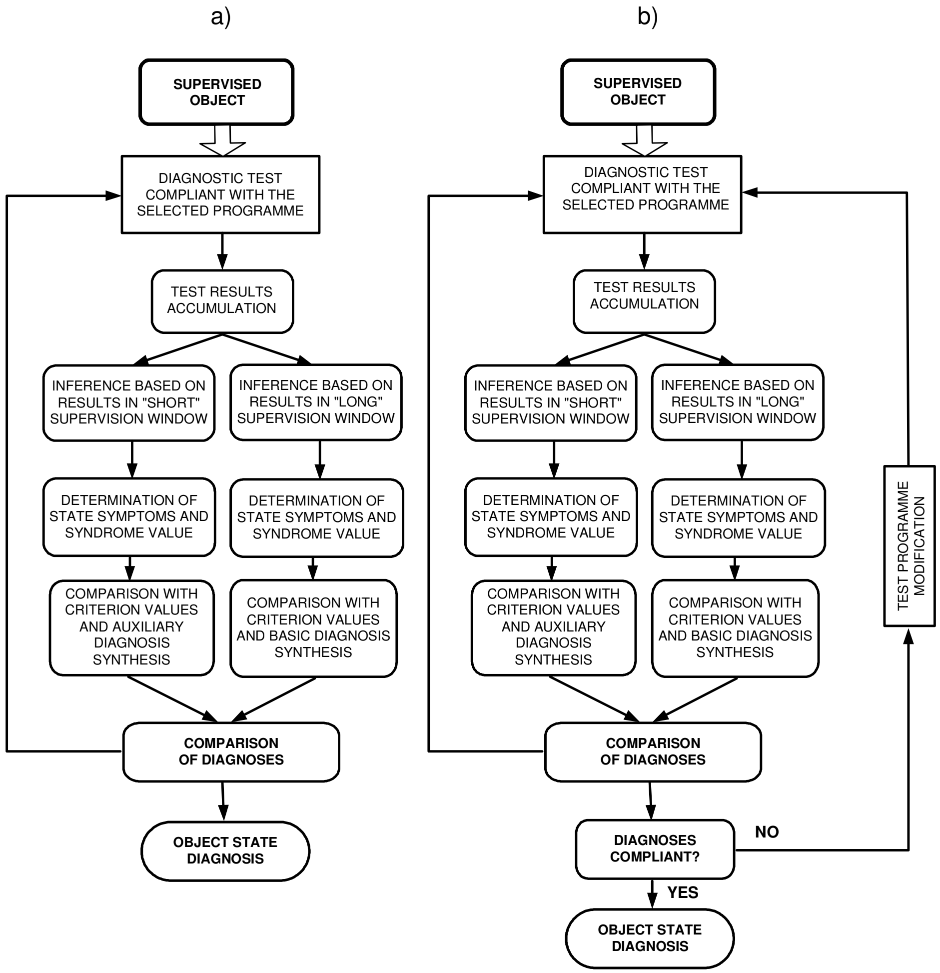

Fig. 4. Algorithm of two-channel diagnostic process: a) with inference based on the diagnoses comparison results, b) with inference and test programme modification based on the diagnoses comparison results

Rys. 4. Algorytm procesu dozorowania dwukanałowego: a) z wnioskowaniem w oparciu o wyniki komparacji diagnoz, b) z wnioskowaniem i modyfikacją programu badania w oparciu o wyniki komparacji diagnoz

In the discussed publications, the following concepts conceived by the authors were applied.

1) The operation of one-time syndrome identification (or N symptoms identification) was named a **diagnostic session**. The operation is cyclically repeated in the supervision process.
2) The **supervision window** is a set of diagnostic sessions; the temporary diagnosis is based on that set. The size of the set (i.e. the window length) is the characteristic number of the assumed diagnostic form. In the simplest

case, the number has a fixed value. During supervision, the supervision window "moves" along the time axis (e.g. by one test result). This consists in omitting the subsequent session of the first result (considered in the previous diagnosis) and consideration of the last result.

3) **One-channel supervision** consists in the creation of one sequence of temporary diagnoses. If the supervision programme remains fixed despite a perceivable change in the value of temporary diagnoses, it is **fixed-programme supervision**. The algorithm in Figure 3a illustrates this.
4) **One-channel variable-programme supervision** consists in a change of the test programme after the perceivable value of temporary diagnoses, which indicates a probable change of state (e.g. uselessness). Variable-programme supervision is illustrated in Figure 3b. A change in programme may entail, for example, a limitation of only one module supervision, the state (symptom) of which raises doubts.
5) **Two-channel fixed-programme supervision** (Figure 4a) consists in performing diagnostic inference in two independent channels but based on the same (diagnostic) test results. The channel with a shorter window reflects weaker stability of temporary diagnoses but generates the negative syndrome information faster. In this case, after the discovery of a negative symptom (and syndrome), no change in the supervision programme is applied; however, the doubts raised may result, for example, in a change of the object use method. Nevertheless, the final diagnosis must be formulated mainly based on information from the channel of longer-window supervision.
6) **Two-channel variable-programme supervision** (Figure 4b) consists in performing diagnostic inference in two independent channels with various window lengths but, in this case, a change of the supervision programme is implemented after the occurrence of doubts as to the state of any of the object modules. The programme change may entail, for example, the application of a shortened programme in which only the uncertain module is supervised. This means testing only one symptom at the cost of abandoning the supervision of the other modules. The final diagnosis is formulated based on the information received from the channel of a longer supervision window (i.e. from the channel with higher stability of temporary diagnoses).

Conclusions

The results of diagnostics and supervision mentioned in the discussed papers and performed in compliance with specified principles, which were received by virtue of simulation, enabled the formulation of the following conclusions.

1. Disturbance and other destructive factors do not exclude the possibility of arriving at diagnoses of the required credibility. Application of syndrome comparison and formulation of diagnosis based on a sufficiently numerous

set of syndromes represent one of the most effective methods of improving the reliability of the diagnostic process.

2. It is possible in the supervision process to arrive at temporary diagnoses with high reliability despite high uncertainty (i.e. low value) of symptoms. However, this requires the application of long "supervision windows" in diagnoses, which results in a delay in detecting a change of state. Therefore, one-channel diagnostics is useful mainly in diagnoses during stable states. In the case of supervising dynamic states, two-channel variable-programme supervision must be applied.
3. The state supervision method described in [3, 4] does not, actually, require the knowledge of the disturbance distribution. It only requires making sure whether the probabilities of the determined positive and negative symptoms authenticity are higher than 0.5.
4. The discussed method does not require a thorough knowledge of *a priori* probabilities of the usefulness of modules of particular objects. Permitted is the assumption that the values of the probabilities equal 0.5.
5. The considered supervision models are useful mainly for supervising states described with specific intervals of the descriptive functions values (symptom values).
6. In the analysed supervision process, no exact measurements of the values describing the object state are required. It is sufficient to register the excesses of the classification threshold values. This shortens the time needed for receiving test results (which is particularly important in supervision processes), simplifies measuring systems and lowers the cost of the systems.

Threshold measuring systems in diagnostics [7, 8, 9, 10, 12, 13, 15, 16]

Active maintenance of the state of usefulness and reliability of an object requires permanent observation (supervision) of the state of a particular object and of the other elements of the system in which the object operates and generates the useful effect.

The performance of this task usually requires that the measuring processes cover a large number of values describing the state of the system elements and the functional processes undergoing therein. This may result in high complexity and cost of the supervision system. Therefore, it is justified to search for and apply simpler and less expensive measuring systems, e.g. **threshold systems**.

A major concept of the threshold measurement method is the assumption that a diagnostic signal is burdened with a significant disturbing component (generally a random one). Filtration of disturbances with the known, classical methods (including the tools applied in typical metrology) is a considerably complex and expensive process. This problem may be omitted by application of threshold measuring systems.

Attention needs to be paid to the fact that threshold measurements consist in the registration of the number of times supervised diagnostic signals exceed the specific threshold values. Based on this information and relatively simple mathematical dependencies mentioned in the discussed publications, it is possible to determine a symptom function. The function becomes the basis for diagnostic inference with regard to the state trajectory of the tested module.

The idea of threshold measurements is explained in Figures 5, 6, and 7.

The basic concept of the measuring system is that two measuring comparators, upper K_g and lower K_d, currently observe the value of the signal $X_D(t)$. Recording the value of the comparator input state takes place at the moment of sampling t_p. This is registered as "one" in the logic circuit if the value of the signal is higher than the value of the upper comparative and measuring threshold X_{Kg} or "zero" if the value of the signal is lower. Comparator K_d with memory connected thereto operates similarly. The logic circuit registers "one" at the comparator output when the signal $X_D(t)$ is lower than the comparative and measuring threshold X_{Kd}. The number of "ones" recorded indicates the number of excesses by the tested signal: "up" on the upper comparative and measuring threshold and "down" on the lower comparative

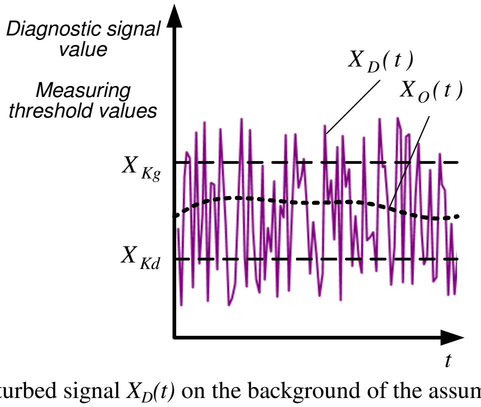

Fig. 5. Illustration of disturbed signal $X_D(t)$ on the background of the assumed measuring threshold values: upper X_{Kg} and lower X_{Kd}.
Identification: $X_O(t)$ – a function describing the state of the diagnosed object (searching function);
$X_D(t)$ – diagnostic signal = measured signal burdened with disturbance:

$$X_D(t) = X_O(t) + X_Z(t)$$

$X_Z(t)$ – disturbance component of a diagnostic signal.

Rys. 5. Ilustracja zakłóconego sygnału $X_D(t)$ na tle przyjętych wartości progów pomiarowych X_{Kg} (górnego) i X_{Kd} (dolnego)
Oznaczenia: $X_O(t)$ – funkcja opisująca stan diagnozowanego obiektu (funkcja poszukiwana);
$X_D(t)$ – sygnał diagnostyczny – mierzony sygnał obarczony zakłóceniami:

$$X_D(t) = X_O(t) + X_Z(t)$$

$X_Z(t)$ – składowa zakłócająca sygnału diagnostycznego

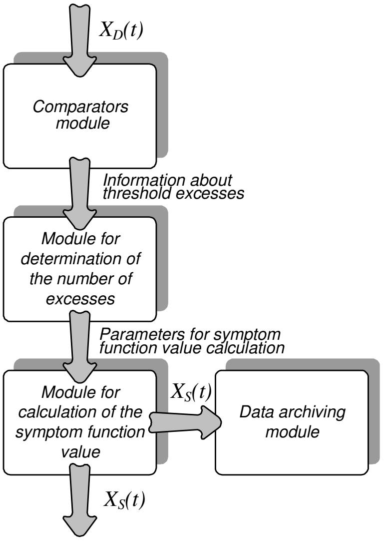

Fig. 6. Functional diagram of the threshold measurement system.
Identification: $X_S(t)$ – symptom function = result of threshold measurements (image of a descriptive function)
Rys. 6. Schemat funkcjonalny układu pomiarów progowych
Oznaczenia: $X_S(t)$ – funkcja symptomowa – wynik pomiarów progowych (obraz funkcji opisującej)

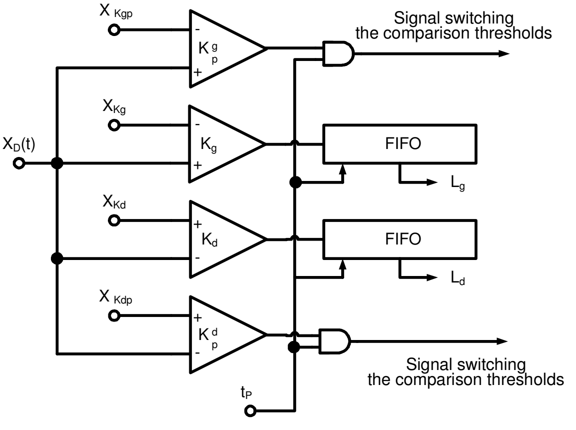

Fig. 7. Diagram of a threshold measuring system.
Identification: FIFO – excess memory block based on FIFO (First In First Out); L_g – number of excesses ("1") up; L_d – number of excesses ("1") down; K_g – upper measuring comparator; K_d – lower measuring comparator; K_{gp} – upper switching comparator; K_{dp} – lower switching comparator
Rys. 7. Schemat progowego układu pomiarowego
Oznaczenia: FIFO – blok pamięci przekroczeń oparty na FIFO (First In First Out); L_g – liczba przekroczeń („jedynek") w górę; L_d – liczba przekroczeń („jedynek") w dół; K_g – komparator pomiarowy górny; K_d – komparator pomiarowy dolny; K_{gp} – komparator przełączający górny; K_{dp} – komparator przełączający dolny

and measuring threshold, respectively. The information is used at a further stage of processing for the generation of the descriptive function image (i.e. symptom function). The other two comparators, upper switching comparator K_{gp} and lower switching comparator K_{dp}, are used for the adaptation (mainly symmetrisation) of the measuring threshold values with regard to the scope of the actual signal values $X_D(t)$.

Conclusion

In the discussed publications, it was theoretically proven and confirmed by simulation that it is possible, with the use of a relatively simple measuring system and adequately selected measuring information processing procedure, to supervise the object state with sufficient accuracy and to make an early discovery of the occurrence of destructive trends. This, on the other hand, allows the application of preventative measures before the functional state of the object passes into a useless state.

An unquestionable merit of the presented supervision method and the supporting measuring system is the low susceptibility of the supervision results to disturbances in the observed value describing the state of the object.

A drawback of the proposed method may be the dependence of error in the representation of the descriptive function $X_O(t)$ on the information possessed about the nature of the disturbance distribution, received as a result of adaptation and the possible calibration of the threshold measuring systems.

Application of the threshold measurement method is particularly beneficial during the supervision of a large number of state describing values and simultaneous testing of these values. The method is distinguished by the application of miniature threshold measuring devices that are inexpensive, simple, reliable, and fast. This facilitates the use and handling of the supervision systems and provides a clear advantage over the supervision systems that include a large number of classical digital devices, particularly with regard to the aspects of economy, reliability, and size.

The symptom functions trajectories $X_S(t)$ determined in the supervision process may become a basis for forecasting excesses of the object state threshold values.

Tests of the correctness of the comparative-threshold supervision method in the aspect of adaptation to the nature of the diagnostic signal [12, 15, 16, 17]

The credibility of the diagnosis defined based on the symptom function depends on the following:

– Proper identification of the disturbance distribution nature with regard to the $X_D(t)$ diagnostic signal;

- Proper adjustment of the measuring threshold levels to the amplitude and rate of change of the $X_D(t)$ diagnostic signal;
- Proper adjustment of the supervision window length to the $X_D(t)$ signal rate of change; and,
- The applied frequency of the $X_D(t)$ signal sampling.

Knowledge of the disturbance distribution nature is required, but it is not needed for correct operation of the system determining the symptom function. In the absence of the possibility to estimate the $X_Z(t)$ disturbance component distribution parameters, measuring and computational algorithm developed for uniform distribution may be applied [12, 15]. Smaller errors in the descriptive function estimation are arrived when using a measuring and computational procedure applied for a specific type of the $X_Z(t)$ random disturbance component distribution. Information about the distribution parameters may be received by supplementing the algorithm of the threshold measurement method with the distribution type testing module. The advantage of this solution is a perceivably higher fidelity of the representation of the object state descriptive function (i.e. smaller differences between the value of the descriptive function and the determined symptom function). A drawback, particularly in the case of high rate of change of the describing signal, is a perceivable delay in receiving the subsequent values of the symptom function, which may be important in the process of supervision of fast changing destructive processes.

The block functional diagram illustrating the idea of the threshold measuring system, supplemented with modules adapting the symptom function synthesis procedure to the nature of the diagnostic signal and the characteristics of the supervised object, is presented in Figure 8.

The length of the supervision window *L* significantly affects the error in the $X_O(t)$ function representation (the longer the supervision window, the smaller the error) and the time delay of the symptom function value determination (the shorter the supervision window, the smaller the time delay) (Figure 9). The characteristics of the method must be taken into account, particularly in the case of supervising quickly changing destructive processes.

A change in the frequency of the $X_D(t)$ diagnostic signal sampling may be required if the destructive process of the supervised object significantly changes its rate of change. Approaching the symptom function value to the limit of the allowed values (e.g. the state usefulness limit) should bring about a reaction in the supervising system through the generation of a signal about the existence of the object state change hazard. This should also result in increasing the frequency of the diagnostic signal sampling for the purpose of more accurate determination of the potential moment of the object state passing from useful into useless. On the other hand, determination that the symptom function graph is monotonic and multi-variable may become the basis for lowering the frequency of the diagnostic signal sampling in order to lower the burden of the measuring and computational system.

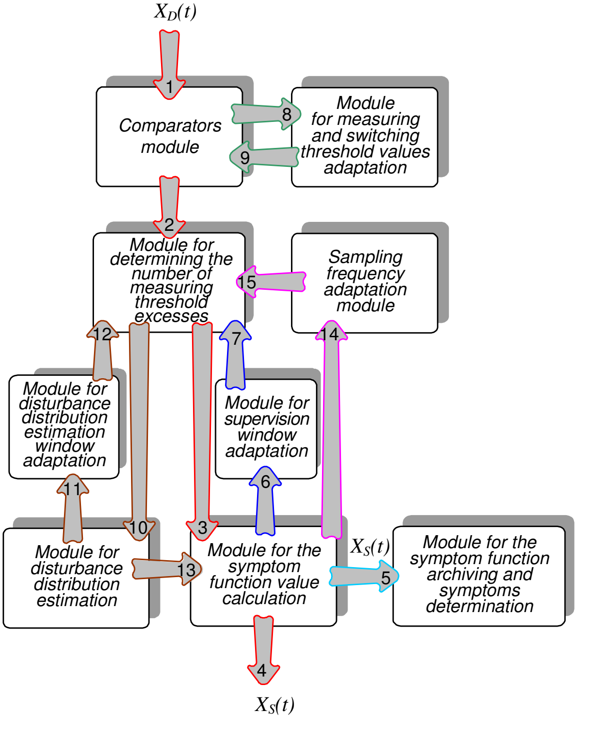

Fig. 8. Pictorial functional diagram of a threshold measuring system in supervision process diagnostics. *Identification:* $X_D(t)$, 1 – diagnostic signal, $X_S(t)$, 4, 5 – symptom function, 2 – information about the relation of the diagnostic signal and the measuring threshold values, 3 – information about the number of measuring threshold excesses in the "supervision window" interval, 6 – information about the symptom function rate of change, 7 – decision on the required "supervision window" length, 8 – information about the relation between the diagnostic signal value and the measuring threshold values, as well as the diagnostic signal value and the switching threshold values, 9 – decision on the value of measuring and switching thresholds, 10 – information about the number of measuring threshold excesses in the "disturbance distribution estimation window" interval, 11 – information about the nature of the disturbance distribution, 12 – decision on the required length of the "disturbance distribution estimation window," 13 – information about the nature of the disturbing component in the diagnostic signal, 14 – information about the symptom function gradient, 15 – decision on the recommended frequency of the diagnostic signal sampling.

Rys. 8. Poglądowy schemat funkcjonalny progowego układu pomiarowego w systemie diagnostycznym realizującym proces dozorowania

Oznaczenia: $X_D(t)$, 1 – sygnał diagnostyczny, $X_S(t)$, 4, 5 – funkcja symptomowa, 2 – informacja o relacji: sygnał diagnostyczny – wartości progów pomiarowych, 3 – informacja o liczbie przekroczeń progów pomiarowych w przedziale „okna dozorowania", 6 – informacja o dynamice zmian funkcji symptomowej, 7 – decyzja o wymaganej długości „okna dozorowania", 8 – informacja o relacji: wartości sygnału diagnostycznego – wartości progów pomiarowych oraz wartości sygnału diagnostycznego – wartości progów przełączających, 9 – decyzja o wartościach progów pomiarowych i przełączających, 10 – informacja o liczbie przekroczeń progów pomiarowych w przedziale „okna szacowania rozkładu zakłóceń", 11 – informacja o charakterze rozkładu zakłóceń, 12 – decyzja o wymaganej długości „okna szacowania rozkładu zakłóceń", 13 – informacja o charakterze składowej zakłócającej w sygnale diagnostycznym, 14 – informacja o gradiencie funkcji symptomowej, 15 – decyzja o zalecanej częstości próbkowania sygnału diagnostycznego

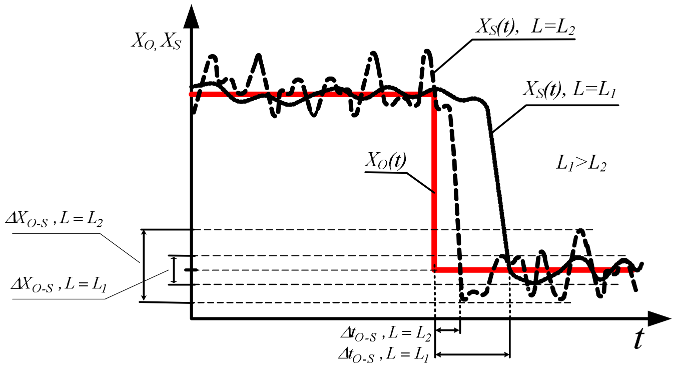

Fig. 9. Illustration of the dependence of delay Δt_{O-S} and the descriptive function representation error ΔX_{O-S} on the length of the supervision window L

Rys. 9. Ilustracja zależności opóźnienia Δt_{O-S} i błędu odtwarzania ΔX_{O-S} wartości funkcji opisującej od długości okna dozorowania L

Conclusion

The research performed, which was mostly simulative with the use of the LabView software, enabled the preliminary determination of the adaptation capacity of the measuring and processing algorithm developed for the needs of threshold supervision. The results received are positive and confirm the thesis that, with relatively small expenditures in hardware and software, the universal nature and usefulness of the threshold supervision method is satisfactory. Errors in the descriptive function representation were minimal in most of the tested cases, despite the variable nature of the diagnostic signal.

Comparative-threshold diagnostics in information transmission systems [6, 8, 11, 13, 14, 18]

Along with the theoretical and opinion-making publications, Professor Będkowski's team attempted several applications of the preferred methods and algorithms in diagnosing real operational systems.

Particularly interesting are papers referring to effective supervision of the information flow process in the industrial data transmission systems.

In article [6], for example, the communication between a *master* computer and *slave* controller is characterised (Figure 10). Methods of diagnosis in the communication system using the *Modbus* protocol are presented. A method of comparative diagnosis of the system is also described. Examples of time redundancy application in comparative diagnostics are provided.

A major element of the diagnostic-therapeutic method proposed for the said object in order to enable the improvement of the messages transmission process reliability is the assumption that the possessed time reserve is sufficient to send and record the same message several times and to compare the contents of the message. If differences are found, a selection of the message deemed to be correct is made.

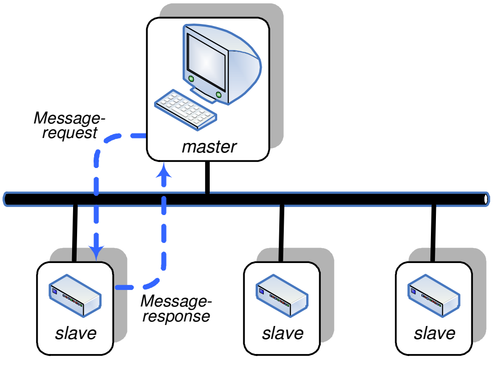

Fig. 10. Communication system based on *master-slave* principle
Rys. 10. Układ komunikacji działający wg zasady *master-slave*

In papers [11, 13, 14], the object of consideration is an example of the implementation of a diagnostic and therapeutic method that is resistant to diagnostic signal disturbance. This based on a threshold measuring system in which messages are sent using two diagnostic stations (local and remote) connected by computer network (Figure 11). The local station measures the threshold values describing the supervised process and synthesises state symptoms (i.e. performs diagnostic tests and measuring inference), while the remote station performs advanced diagnostic inference (e.g. structural or functional) and develops therapeutic decisions.

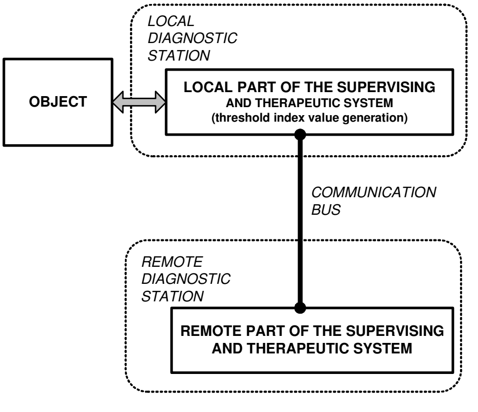

Fig. 11. A system provided with threshold measuring system in the local station and inference/decision-making system in the remote station
Rys. 11. Układ z progowym układem pomiarowym w stacji lokalnej oraz z układem wnioskująco-decyzyjnym w stacji odległej

Application of this solution has a positive impact on the communication load (only binary values are sent) and simplifies the measuring system (threshold measurements). This is very important in the case of distributed information transmission systems, because it enables the creation of time redundancy, which may be used, for example, in multiplying the transmission of messages for improving transmission reliability.

In paper [11] considerations regarding supervision in a territorial distributed message transfer system continue. An important extension of the comparative-threshold supervision method concept is the assumption of a newly developed structure of both the local and the remote stations (Figure 12).

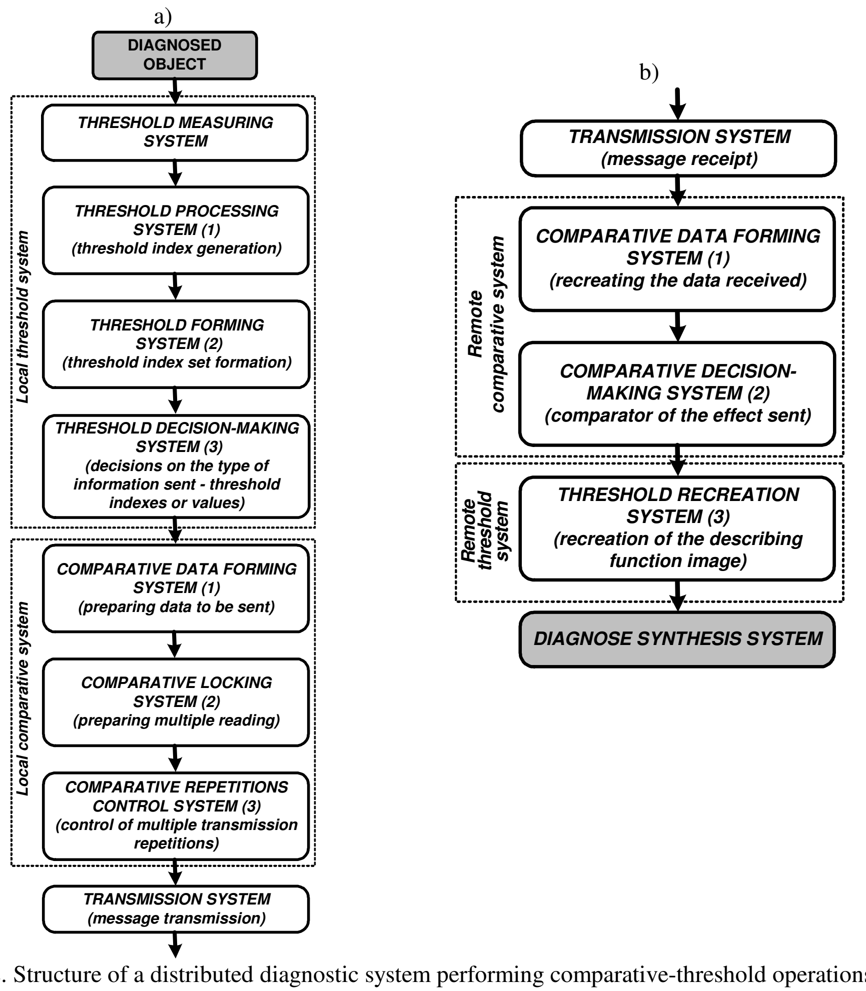

Fig. 12. Structure of a distributed diagnostic system performing comparative-threshold operations: local diagnostic station structure; b) remote diagnostic station structure

Rys. 12. Struktura rozproszonego systemu diagnostycznego realizującego operacje progowo-komparacyjne: a) struktura lokalnej stacji diagnostycznej; b) struktura odległej stacji diagnostycznej

The presented supervision algorithm may perform, for example, in the functional block language FBD or in the industrial controller AC800F [18].

Conclusion

The performed attempts of comparative-threshold diagnostic (and supervision) method implementation in a real information transmission system with the use of an industrial controller proved that the assumed diagnostic (and supervision) procedure concept is correct and useful. Application of the comparative-threshold diagnostic method contributes to the high credibility of diagnoses and, as a result, improves the reliability of the whole operating process by performance of rational therapeutic actions (based on credible information).

Summary

The team continues to focus on diagnostic (and supervision) process reliability improvement in variable and/or unfavourable operation conditions. In particular, a thorough study of the method and the system of threshold measurements and diagnostic inference based on the threshold measurement results have been carried out. An element that still needs to be more precise is the universal algorithm of the threshold measuring system operation in the aspect of the diagnostic signal disturbance nature. It is also assumed that work will continue on the practical implementation of the comparative-threshold method in the supervision of information flow processes in an industrial controller.

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Niezawodność progowo-komparacyjnych procesów diagnozowania

S t r e s z c z e n i e

Prace naukowe realizowane w latach 2006–2011 w zespole prof. Lesława Będkowskiego można sprowadzić do następujących dwu wiodących zagadnień:
- niezawodność diagnoz opartych na niepewnych symptomach stanu;
- metody i procedury diagnozowania i dozorowania odporne na zakłócenia.

Efektem przeprowadzonych rozważań i analiz oraz zrealizowanych badań są opracowania, które można zgrupować w kilka merytorycznie skorelowanych wątków:
- diagnozowanie z wielopoziomową komparacją niepewnych symptomów i syndromów stanu obiektu;
- niepewność w procesach diagnozowania i dozorowania;
- progowe układy pomiarowe w systemach diagnostycznych;
- badania właściwości progowo-komparacyjnej metody dozorowania w aspekcie adaptacji do charakteru sygnału diagnostycznego;
- progowo-komparacyjne diagnozowanie w systemach transmisji informacji.

Podstawowe elementy powyższych zagadnień i wnioski wynikające z uzyskanych efektów badań są treścią niniejszego opracowania.