Intelligent decision support system for assessing the risk of failures of complex technical systems

https://doi.org/10.31713/MCIT.2023.055

Alexey Vychuzhanin
National University «Odessa Polytechnic»
Odessa, Ukraine

Abstract—**A decision support system has been developed that allows assessing the risk of failure of elements and components of complex technical systems using artificial intelligence. The proposed algorithm for the functioning of a decision support system implements the task of automating the process of assessing the technical condition of complex systems. The use of the proposed decision support system for assessing the technical condition of complex systems will improve the reliability of operating systems with insufficient information about their technical condition.**

Keywords—complex technical systems; reliability; risk of failure; decision support; algorithm.

I. Introduction

To assess the reliability of complex technical systems (CTS), various methods based on the methods of probability theory and mathematical statistics have been developed and applied, which makes it possible to automate the process of assessing the reliability of elements and components of systems [1–4].

However, the stages associated with supporting decisions made to ensure reliability based on the results of its assessment for CTS are often not automated. As a result, the quality of decisions made to ensure reliability indicators of the CTS significantly depends on the qualifications of the personnel servicing the system [5].

Evolution in information processing leads to the actualization of the task of not only automating the process of assessing the reliability of elements and components of complex systems, but also to the transfer of part of the intellectual sphere of human activity to the sphere of automation of making and supporting management decisions in the field of ensuring the reliability of CTS [6].

The creation of intelligent decision support systems (DSS), in the context of progress in the field of information systems and technologies, finds significant application in solving complex, difficult to formalize problems, in particular, diagnosing the reliability of CTS.

Distinctive features of problems that are difficult to formalize are the incomplete amount of initial data of the problem being solved, inaccuracy, heterogeneity, and significant computational complexity [7].

The purpose of the study is to ensure the reliability of elements and components of operated CTS based on the use of an intelligent DSS for assessing their technical condition.

The objectives of the study are to develop a DSS with insufficient information for assessing the technical characteristics of complex systems.

II. Main part

To assess the technical condition of the CTS, a DSS is proposed. In such a system, unlike classical artificial intelligence systems, the following is carried out: modeling the subject area, and not the actions of an expert; application of probability theory and decision-making theory instead of attempts to “take into account uncertainty” using production rules of the form “IF.” For the practical implementation and operation of DSS, it is necessary to link the developed models to an expert system containing calculated, experimental, and data acquired by experts during the operation of the CTS.

To support decision-making on assessing the risk of CTS failures based on a priori and a posteriori data, as well as when searching for failed elements and system components in order to increase the efficiency of their operation, a method based on dynamic Bayesian trust networks (DBTN) is used [8, 9].

The use of DBTN makes it possible to determine with great accuracy the elements and components of the CTS that are closest to the critical state and their failure.

The task is solved by using a constant system of polling all elements of the system at its various levels for a specific period of time.

This allows, with the help of DBTN, to study extreme situations and accurately determine the critical values of the risk of failure of elements and components of the CTS.

The reliability of the STS can be assessed based on the results of diagnosing the technical condition of elements and components in the form of a risk of failure [10–12].

The construction and study of the DBTN probability of loss of performance, assessment of the risk of failure of elements and components of the CTS was carried out using the GiNIe software product [13].

The decision support strategy used when searching for failures of elements and components of ship CTS consists of a number of stages (Fig. 1).

The developed DSS operates in the following decision support modes:

- mode of integral assessment, in which the system indicates the possible degrees of risk of failure of elements and components of the vehicle at different times. Evaluates their criticality. Forms recommendations for the restoration or replacement of elements and components depending on their impact on the CTS;
- differential assessment mode, in which the system evaluates each of the hierarchies of technical systems according to the category "system-element". Generates recommendations similar to the first mode;
- search mode, in which the system models possible malfunctions and failures of elements and components with various target search functions. The goals of the search are to find critical and vulnerable points of the system, to evaluate various options for preventing the system.

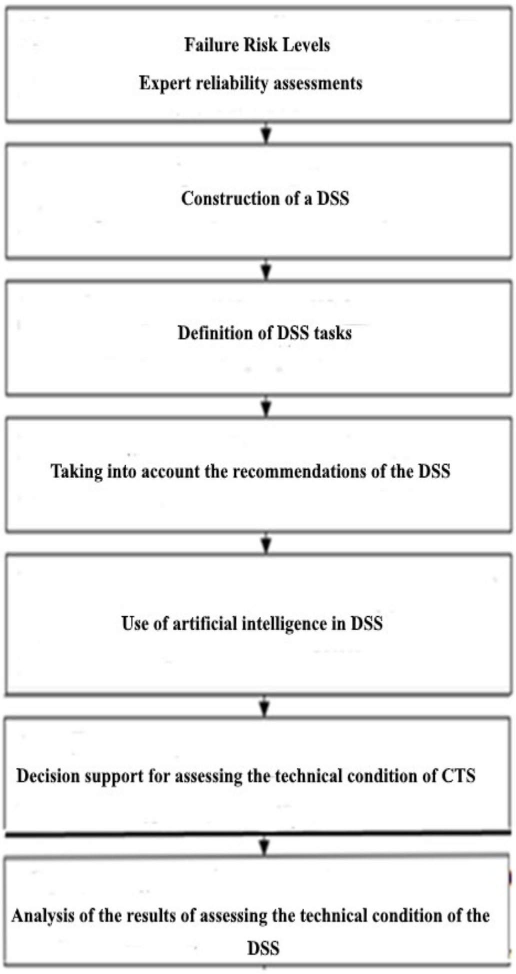

Figure 1. Decision support strategy when searching for failures in STS

The model of an intelligent system m for assessing and predicting the risk of failure of components of a complex technical system in the form of a DBTN can be written as follows:

$$< M, S, R, L >,$$

where M – is the set of subsystems (elements) of the CTS; S – a set of intersystem (interelement) links of CTS; R – a set of diagnostic assessments of the risk of failures of subsystems (elements), intersystem (interelement) links of CTS; L – mapping of connections between the sets M, S and R, based on the CTS diagnostic model.

The initial data for constructing an intellectualization model for assessing the technical condition of complex systems using the example of a ship power plant (SPP) are: the diagram and principle of operation of the system; probability of failures of system elements and components [14].

When modeling the DBTN SPP (Fig. 2), for various values of the risk of failure of a component at the input of the network, the values of the risk of failure of functionally interconnected elements and components were determined for 20,000 hours of operation of the SPP.

Symbols of elements and components of the control system in DBTN (Fig. 2): Fire fighting system – FFS; Remote automated control system of the main engine – RACSME; Main engine – ME; Control system for propulsion and steering complex –CSPSC; Transfer of power from the main engine to the propeller – TPMEP; Propulsion and steering complex – PSC.

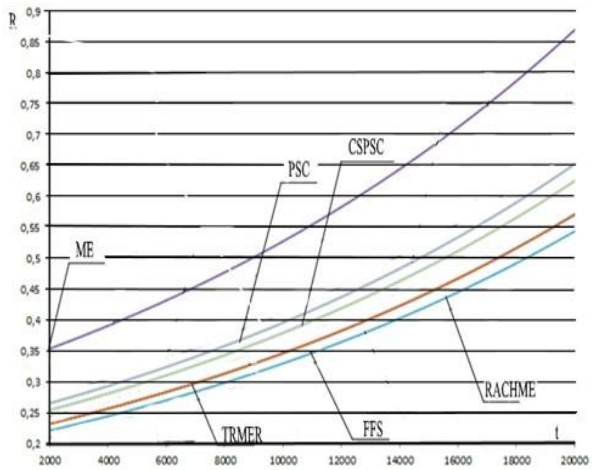

Figure 2. Risk of failure of elements and components of the power plant

The intended purpose of using DBTN in assessing the risk of failure of elements and components of CTS is a posteriori conclusion.

A priori data are converted into a posteriori assessment of the risk of failure, which in turn is a priori information for processing new information. The posterior inference is based on the data analysis procedures resulting from the use of DBTN.

The proposed principle of operation of an intelligent system, its structure using the example of an SPP, reflected in the method and model for assessing the risk of failure of elements and components of the CTS, should be considered as conceptual.

The described method, the presented model of an intelligent system for assessing the risk of failures of

STS on network infrastructures, as a result of the studies carried out, confirmed the relative insensitivity to incomplete data of elements and components of the system.

The functioning of the developed DSS is based on an assessment of the risk of failure of elements and components of the CTS. Those on criteria that reflect taking into account the specifics of the interaction of various elements and components, the correlation of changes in the values of their parameters under various emergency operating conditions of a complex system.

Application of the obtained research results allows us to ensure:

- formation of principles for the construction and operation of an intelligent system for diagnosing and predicting the risk of CTS failures;
- creation of an intellectualization model for assessing the technical condition of the risk of CTS failures based on diagnostic criteria, which is relatively insensitive to incomplete technological data of elements. components of complex systems;
- creation of an intellectualization model for assessing technical condition, based on the use of a priori information about failures, connecting the types of states of elements, components of complex systems and their diagnostic features in the form of failure risk;
- identifying the most vulnerable elements and components of the CTS and solving the problem of determining the causes of their failures depending on the risk of failures when diagnosing the technical condition of systems.

III. Conclusion

The results of developing a diagnostic model for a complex technical system with incomplete technological data and its implementation in an intelligent system for assessing the risk of failure of elements and components using the example of a ship's CTS made it possible to obtain a priori information about the technical condition.

Types of technical condition of elements. components are identified on the basis of diagnostic features of a complex system using the example of a ship power plant.

The technical condition of a complex system was assessed using a posteriori inference in Bayesian belief networks. In the course of the research, the results of the functioning of the intelligent system for diagnosing the risk of failures of the CTS, which allows identifying the most vulnerable elements and components of the system, were assessed.

The presented model for assessing the risk of failure of elements and components can be considered as a conceptual model of an intelligent system for assessing failures of complex technical systems on network infrastructures, which is relatively insensitive to incomplete technological data.

The use of the developed method and model when searching for the causes of failures in complex technical systems makes it possible to control the values of the risk of failures in systems when information about failures in their structures is received.

References

[1] I. Lazakis, “Advanced ship systems condition monitoring for enhanced inspection, maintenance and decision making in ship operations,” Transportation Research Procedia, vol. 14, 2016, pp. 1679, 1688. URL: https://doi.org/10.1016/j.trpro.2016.05.133.

[2] V. Vychuzhanin, and N. Rudnichenko, “Assessment of risks structurally and functionally complex technical systems,” Eastern-European Journal of Enterprise Technologies, vol. 1(2), 2014, pp. 18–22. URL: https://doi.org/10.15587/729-4061.2014.19846

[3] ISO 13381-1:2015, “Condition monitoring and diagnostics of machines – Prognostics – Part 1: General guidelines.” [valid from 2015-03-01], Vernier: ISO copyright office, 2015.

[4] V. Vychuzhanin, and N. Rudnichenko, “Metody informatsionnykh tekhnologiy v diagnostike sostoyaniya slozhnykh tekhnicheskikh sistem,” Odesa: Ekologiya, 2019.

[5] M. Zhang, J. Montewka, T. Manderbacka, P. Kujala, and S. Hirdaris, “A Big Data Analytics Method for the Evaluation of Ship - Ship Collision Risk reflecting Hydrometeorological Conditions,” Reliability Engineering & System Safety, vol. 213, 2021, 107674. URL: https://doi.org/10.1016/j.ress.2021.107674.

[6] V. Vychuzhanin, N. Shibaeva, A. Vychuzhanin, and N. Rudnichenko, “Intellectualization Method and Model of Complex TechnicalSystem’s Failures Risk Estimation and Prediction,” The Six International workshop on Computer Modeling and Intelligent Systems (CMIS-2023, May 12, 2022), Zaporizhzhia, Ukraine. CEUR Workshop Proceedings, vol. 3392, 2023. pp. 130–140.

[7] A. Vychuzhanin, “Intelligent system for assessing and forecasting the risk of failure of components of a complex technical system,” Informatics and Mathematical Methods in Simulation, vol. 12(3), 2022, pp. 154–161. URL: https://doi.org/10.15276/imms.v12.no3.154.

[8] F. Jensen, “Bayesian Networks and Decision Graphs,” Berlin: Springer, 2007.

[9] C.R. Wang, and C. Guan, “A Bayesian inference-based approach for performance prognostics towards uncertainty quantification and its applications on the marine diesel engine,” ISA Transactions, vol. 118, 2021, pp. 159–173.

[10] IEC 31010:2019 “Risk management — Risk assessment techniques.” [valid from 2019-06], Geneva: IEC Central Office, 2019.

[11] N. Rudnichenko, V. Vychuzhanin, A. Polyvianchuk, and V. Mateichyk, “Complex Technical System Condition Diagnostics and Prediction Computerization,” The Six International workshop on Computer Modeling and Intelligent Systems (CMIS-2020, April 27 - May 1, 2020), Zaporizhzhia, Ukraine. CEUR Workshop Proceedings, vol. 2608, 2020, pp. 42–15. URL: https://doi.org/10.32782/cmis/2608-4.

[12] M. Asuquo, J. Wang, and L. Zhang, “An integrated risk assessment for maintenance prediction of oil wetted gearbox and bearing in marine and offshore industries using a fuzzy rule base method,” Proceedings of the Institution of Mechanical Engineers, Part M. Journal of Engineering for the Maritime Environment, vol. 234(2), 2020, pp. 313–331. Doi: 10.1177/1475090219899528.

[13] “Genie9: Making Local Backup Easy and Affordable - Genie9.” [Online]. Available: https://www.zoolz.com/genie9/. [Accessed: September 19, 2023].

[14] D. Boullosa-Falces, and L. Barrena, “Monitoring of fuel oil process of marine diesel engine,” Appl. Therm. Eng, vol. 127, 2017, pp. 517–526.