

AUTOMATED DIAGNOSTIC OF TECHNOLOGICAL PROCESSES BY METHODS OF HIERARCHICAL MODELING AND DIAGNOSTIC PROCEDURES

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Анотація

У цій статті досліджується впровадження автоматизованої діагностики систем з використанням ієрархічного моделювання, розглядаючи виклики аналізу складних технологічних процесів. Запропоновано метод, який розділяє систему на менші, керовані підсистеми, що дозволяє ефективно проводити поетапну локалізацію несправностей. Застосовуючи спеціалізовані діагностичні алгоритми на кожному ієрархічному рівні, цей підхід спрямований на значне прискорення процесу діагностики, покращуючи швидкість і точність виявлення несправностей.

Ключові слова: система діагностики, ієрархічне моделювання, діагностичні процедури, аналіз несправностей, компонентна модель, автоматизовані системи, логічні графи, локалізація проблем, діагностичний аналіз, алгоритми діагностики.

Abstract

This paper investigates the implementation of automated system diagnostics using hierarchical modeling, addressing the challenges of analyzing complex technological processes. The proposed method divides the system into smaller, manageable subsystems, enabling efficient, staged fault localization. By applying specialized diagnostic algorithms at each hierarchical level, the approach aims to significantly accelerate the diagnostic process, improving the speed and accuracy of fault detection.

Keywords: diagnostic system, hierarchical modeling, diagnostic procedures, fault analysis, component model, automated systems, logic graphs, problem localization, diagnostic analysis, diagnostic algorithms.

Introduction

Diagnosing modern technological systems is becoming increasingly challenging due to their multi-component structure, where individual elements interact with each other and may contain nested subsystems. With the increase in the number of components, the complexity of diagnostic analysis and the duration of calculations increases, regardless of the required accuracy and the impact of new elements on the factors under study. A one-level diagnostic methodology generates too many potential diagnoses, which makes it difficult to verify them quickly.

The purpose of this paper is to study hierarchical modeling to create a system of diagnostic procedures aimed at analyzing technological processes. The problem of increasing complexity can be solved by forming a model in which the vertical position in the structure reflects a certain level of the analyzed components. This approach will facilitate effective diagnosis of technological processes with the possibility of fault localization.

Results of the study

Among the main methods of analysis, approaches based on logical thinking, as well as knowledge and cause-and-effect relationships, are of particular importance. Since precise mathematical models can be applied to only a limited number of systems, knowledge engineering and computational intelligence methods remain universal for any complex system (although the level of accuracy may vary depending on their structure).

Knowledge-based methods evaluate discrepancies between expected and actual system behavior, where predicted behavior is determined based on a model. This approach, known as sequence-based

diagnostics, does not require prior expert knowledge or training, which makes it possible to diagnose even new systems for which there is no historical data.

To analyze technological systems, existing models of correct behavior that were created during the design stages can be used. The basic principle of diagnostic models is based on the representation of the system as a set of components and their interconnections. The diagnosis of such a system takes place in two stages: first, faults are detected, and then they are localized. The input parameters of the system are analyzed and compared with the calculated output values of the model and actual observations. Significant discrepancies between these indicators indicate the presence of a malfunction.

In case of detection of abnormal behavior, a localization procedure is performed to identify the faulty components. Conflict sets contain elements that participate in the formation of the system's output data, where deviations are recorded. At least one of these components is the cause of the malfunction, and the subsequent diagnostic process should cover at least one element from each conflict set.

Causal diagnostic methodologies are based on the analysis of cause-and-effect relationships that describe the correct and incorrect behavior of the system. They typically use basic logical operators (AND, OR, NOR) to model the relationships between symptoms and causes of faults. Despite the simplicity of this approach, it may not be effective enough for complex systems.

It is also possible to use expert logic graphs as a variant of the causal approach. They represent cause-and-effect relationships in the form of an acyclic oriented graph, where nodes are responsible for symptoms and arcs are responsible for the connections between them. Nodes can be represented by logical operators: AND (conjunction), OR (disjunction), and NOT (negation). Diagnostic conclusions are formed by distributing the states of nodes in the graph and analyzing their logical values.

Another approach based on hierarchical modeling of system components is proposed. In this approach, the system structure is presented as a set of nested subsystems, where each of them is analyzed separately. The diagnostic procedure determines the level at which a malfunction is likely to occur, after which a targeted analysis of a specific subsystem is performed. This approach allows you to first quickly assess the overall state of the system, and then conduct a more detailed study of the identified problem area.

Conclusions

Based on our analysis, we have developed an approach to diagnostic procedures for complex systems using hierarchical modeling. This opens up opportunities for further integration of artificial intelligence methods, in particular approaches based on consistency and causality.

In future research, it is planned to develop a formal concept of a general model for modeling hierarchical structures of complex systems, a methodology for hierarchical diagnostics, and experimental software to support the analysis of technical systems.

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