Chapter 18

STATE MONITORING ALGORITHMS FOR
COMPLEX DYNAMIC SYSTEMS

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18.1. Introduction

In the case of industrial processes (systems), diagnoses should be formulated online and in real time. Such a method of diagnosing is called system state monitoring (Kościelny, 2001). This chapter presents state monitoring algorithms for complex industrial installations.

At the beginning, problems with diagnosing complex dynamic systems are formulated. Taking them into account and solving them is necessary for the correct operation of each industrial diagnostic system. A general strategy of state monitoring, as well as its particular phases such as fault detection, isolation, identification, and the detection of a comeback to the normal state, is presented. State monitoring algorithms using the DTS (Dynamic Tables of State), the F-DTS, as well as the T-DTS method are given. They differ in the notation method used for diagnostic relations (the binary diagnostic matrix, the information system), inference rules (classical or fuzzy logic, series or parallel inference), as well as the method of taking into account the dynamics of symptoms that appear in the system. The presented examples illustrate the features of particular system state monitoring algorithms.

§ The work has been carried out in part within the EU’s 5th General Programme: CHEM-Advanced System of Decision Aiding for Chemical/Petrochemical Processes, as well as the project No. 134/E/365/SPUB/DZ179/2001 of the State Committee for Scientific Research in Poland, KBN.

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18.2. Practical problems

When diagnosing complex industrial installations, there occur many problems, including the following:

- Different symptoms caused by the same fault occur at different moments of time. The dynamics of the occurrence of symptoms should therefore be taken into account in inference algorithms.
- The system structure changes during its operation. Particular parts of the installation can be switched off or on. Therefore, the set of measuring devices also changes.
- Single as well as multiple faults can occur.
- The number of possible states of the system is very high especially when taking multiple faults into account. Therefore, skilful limiting of the set of the analysed states of the system is advisable.
- Knowledge about the diagnosed system is not identical. System models are known for certain parts of the installation but for others, only heuristic dependences or limits are available. Moreover, knowledge usually tends to grow deeper during the operation of the diagnostic system. State monitoring systems should therefore allow integrating different fault detection methods with one isolation algorithm. The possibility of an easy expansion of the diagnostic system also ought to exist during the operation of the diagnosed system, when knowledge about it becomes deeper and deeper.
- In the case of some systems, diagnosing time may have to be limited. Diagnoses should be sufficiently quick in order to ensure the possibility of undertaking effective preventive actions in states with faults.

18.2.1. Dynamics of the occurrence of symptoms

The diagnosed system is a dynamic one; therefore a certain amount of time elapses between the occurrence a fault and a measurable symptom of its appearance. The time depends, among other things, on the dynamic properties of the tested part of the system. The same fault is detected by different tests that control this fault after non-identical intervals of time. Therefore, if a set of diagnostic signals that detect a particular fault is considered, only some of the signals have values being the fault symptoms at a certain moment of time after the fault occurs. Only after a longer time interval do all of the signals have values which testify the occurrence of the fault. In this situation, we do not take into consideration all problems concerning the uncertainty of the occurrence of symptoms.

False diagnoses can be generated if one does not take into account the dynamics of the occurrence of symptoms. The problem is illustrated with the help of an example. Let us consider a binary diagnostic matrix (Table 18.1) created for four tests shown in Table 3.10.

Let us assume that the fault $f_3$ appeared. The fault is detected by diagnostic signals $s_2$, $s_3$, and $s_4$. Let us assume (ignoring physical realities in this