On Diagnosability of Petri Nets

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A discrete event system (DES) is a dynamic system that evolves in accordance with the abrupt occurrence, at possibly unknown irregular intervals, of physical events. DES's arise in many domains. Typical applications are found in computer networks, flexible manufacturing systems, operating systems, database systems, and so on. By the requirement for the effective control of DES's, there have been many researches from various viewpoints.

The need for accurate and timely diagnosis of system failures, in the interests of safety, reliability, and economy, has prompted widespread interest in the area of failure diagnosis both in industry and in academia. A variety of schemes, differing both in their theoretical framework and in their design and implementation philosophy, have been proposed. The method based on the control theory of the DES's proposed by Wonham and Ramadge is also one of them.

By this framework, a system is expressed by the automaton and the behavior is expressed as a set (namely, language on a event set) of the event sequences to generate. There are two kinds of events, events which can be observed (*observable events*), and events which is not so (*unobservable events*). When it is possible to detect faults in the past by observing finite event history, the system is called *diagnosable*. The diagnosability has been discussed on general discrete event systems. On the other hand, to handle concurrent/asynchronous/distributed DES's, Petri nets have advantage against conventional automata, and are widely used in applications. In this research, we apply the results on DES's expressed by automata to those by Petri nets, and derive conditions for the diagnosability.

First of all, we introduce Petri nets with a labeling function on the set of transitions, called *labeled Petri nets*, to represent the observability. By the feature of the labeling function, the class of labeled Petri nets can be decomposed into the following two classes:

- *Free-labeled Petri nets*: Each transition has a label from the empty label or a unique label.
- *General-labeled Petri nets*: Labeled Petri nets without the above restriction.

We first show that the diagnosability of a general-labeled Petri net can be reduced to that of a free-labeled Petri net.

We study the following problems on the diagnosability.

1. Structural diagnosability problem: A labeled Petri net structure C^ℓ and a fault transition t_f are given. Is (C^ℓ, M_0) diagnosable w.r.t. t_f for any marking M_0 such that (C^ℓ, M_0) is live?
2. Initial-making-dependent diagnosability problem: A live labeled Petri net PN^ℓ and a fault transition t_f is given. Is PN^ℓ diagnosable w.r.t. t_f?

For the structural diagnosability problem, we obtain a necessary and sufficient condition for the diagnosability. This condition is derived by using the notion of T-increment vectors, which is a vector that does not decrease the number of tokens in every place. Moreover, we show two methods to estimate *the delay* for the diagnosis, i.e., it is the number of occurring events between the fault event and the time at which we can know the fault event has surely occurred. We show two methods, one is a search algorithm for bounded Petri nets, and the other is a method for unbounded Petri net to compute an upper bound of the delay.

Finally, for the initial-making-dependent diagnosability problem, we show a necessary and sufficient condition for the diagnosability. At the present time, however, it is unknown whether the condition is decidable for unbounded Petri nets or not. This is one of future work.

The paper is organized as follows. In Chapter 1, we describe backgroud of this research. In Chapter 2, we define several notations and necessary concepts. In Chapter 3, the diagnosability in DES's are described. In Chapter 4, we define the diagnosability of Petri nets, and also present two problems to be solved, the structural diagnosability problem and the initial-making-dependent diagnosability problem. In Chapter 5, we show necessary and sufficient conditions for these problems. Chapter 6 is the conclusion. In Appendix, we show the algorithm to compute the delay.