Research on Embedded PLC Control System Fault Diagnosis: A Novel Approach

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Abstract. This paper presents an approach to a novel and efficient diagnostic system for PLC controlled manufacturing systems. A general structure of the diagnostic system is implemented, which is the extension of an existing diagnostic system we have developed in recent years. We artificially get the diagnostic knowledge by model-based methods from the pneumatic and hydraulic circuit diagrams and the PLC program. Knowledge is embedded in the PLC as compared to more useful form, described in the manufacturing system designers keep their minds functionality and business logic. These models include the design and manufacturing systems engineering knowledge to make the diagnosis. Our proposed diagnostic system ca continuously acquire data from the PLC, identify possible faults, search for their causes and suggest corrective actions.

Introduction

In order to meet the quest for automation and flexibility, many complex manufacturing systems are controlled by Programmable Logical Controllers (PLC) [1]. This is because that PLC's are adaptable, modular, user-friendly and acquired at low cost. However, because of PLC's inflexible programming system, their capability in fault detection and diagnosis is limited. Operation faults associated with PLC control processes often puzzle the maintenance personnel at workshop level. Statistics shows that these faults occur most often (about 70%) among all kinds of faults, and when such a fault occurs, about 80% of downtime is spent locating its source and only 20% is spent on the repair [2]. The availability and productivity of these automated manufacturing systems can be improved by shortening their downtime resulted from faults. This has led to the development of automatic diagnostic tools or systems. Typically, when a failure occurs, maintenance personnel will check Input / output of the PLC (I / O) in a first. Then, he / she will try Use PLC software debugging tools to track the signal Help PLC and PLC on the source code, documentation Machine design and observed until the input signal, This is caused by the failure, to be found. Sometimes, it does work with sacrifice of time. However, this diagnostic method has been found by the following bottlenecks [3]: (1) The PLC programming devices do not support automatic analysis of the logic circuits, which could help in finding the most likely causes of the fault. (2) Most PLC code presented by the function block graphics Chart or ladder logic. It is difficult to read and The complex functions of the program is difficult to recover. (3) There is a huge amount of documentation on the mechanical, electrical and operative design of a complex system. (4) The maintenance personnel's observation of the manufacturing system may be wrong or incomplete, which may lead to incorrect diagnosis.

In this paper, we employ knowledge-based techniques to implement intelligent and real-time diagnosis of PLC controlled manufacturing systems. The diagnostic system is constructed mainly by associating the machine states (indicated by PLC signals) with the possible faults. The association which is represented as diagnostic knowledge in the diagnostic system, is acquired by an artificial method or using model-based methods.

Concepts of PLC Control System and Diagnostic System Design

Mechanism of the PLC System. In a manufacturing system, PLC is used to control the behaviors of the system. The operating actions of the system and the sequence of these actions were edited beforehand into the control program by the manufacturer. The control program sets a series of operations of the manufacturing system, which tells the PLC how to control a system. The control loop of a PLC and the overall model of a PLC controlled manufacturing system can be described as in Figure 1 and Figure 2 respectively [4]. PLC control of manufacturing system according to the control procedures, this is an embedded controller. When a fault occurs, all the sensor or actuator state save as an array of input and output signal or mark in PLC memory. Therefore, the PLC program is diagnosed on the basis of manufacturing system controlled by PLC.

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For (ever)
{
    Read all PLC inputs;
    Evaluate the PLC program;
    Set all PLC outputs;
}
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Fig. 1 The PLC Control Loop

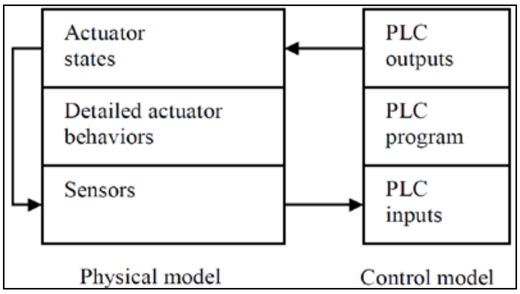

Fig. 2 The Overall Model for a PLC

Design of Diagnostic System. From Figure 2 we can know that, when diagnosing a PLC controlled manufacturing system, we always have to consider both of its two sub-systems, i.e., the control system (PLC) and the physical system (the system being controlled), which are linked by wiring diagrams. These wiring diagrams are maintained separately from the PLC program and the pneumatic and hydraulic circuit diagrams those typically constitute the documentation for the physical system. Usually in order to understand the behavior of the manufacturing system, we need to understand how both of its two sub-systems behave and how they interact with each other [1]. Monitoring automated manufacturing systems PLC control can be characterized by discrete state error in the PLC memory signal. The running state of these signals by discrete points of manufacturing system, it also can diagnose. These signals can be directly obtained by time interaction (RS232 series interface) I/O board and computer diagnosis system of PLC (this can also through a variety of information technology level, this is the use of local area network) the main contents of the fault diagnosis system. It can be seen that, an automatic diagnosis of PLC controlled manufacturing systems is to use specific reasoning algorithms to search all the possible fault causes under the help of the relevant diagnostic knowledge as well as real-time data. Therefore, a knowledge-based system scheme is suitable for the diagnosis of complex PLC controlled manufacturing systems. The knowledge acquisition task involved in the development of such a system is extremely time-consuming, thus more disincentive. If all the diagnostic knowledge is acquired artificially from a large amount of documentation for the physical systems, they will often be inconsistent and incomplete, and therefore lead to false diagnosis or inaccurate diagnosis. Model-based knowledge acquisition mechanisms can help to solve this problem, which will result in the improvement of knowledge acquisition and diagnosis efficiency.

Acquisition of Diagnostic Knowledge

Artificial Knowledge Acquisition. In the manufacture of PLC control system, some system of self-protection warning. Each alarm is usually expressed by a combination of a PLC signal and multi carrier signal. These alarms protect the manufacturing system from working in an error condition. An alarm appears when there is a fault such as: (1) the temperature is too high, (2) the pressure is too low, (3) the circuit is broken, (4) the oil level is not high enough, (5) an error operation is made. Figure 3 is an example of an elevator in a PLC controlled production line. When there is a control command, a relevant valve will then be activated and make the elevator move the table to its top or bottom position. At the top and bottom positions of the table, there are two limit switches (LS1 and LS2) which are used to detect the current position of the table.

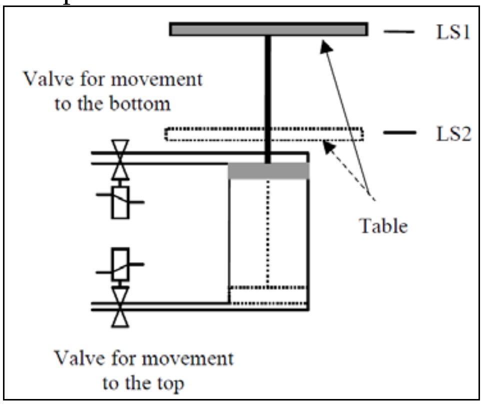

Fig. 3 The Elevator Example

Model based on PLC Control Sequence. This model consists of a certain number of system states and state changes in the PLC control sequence. It describes the sequential changes of the manufacturing system operating states. The action in a certain step is not only related to the control commands in this step, but also related to the step conditions in the previous step. The current step can only be started under the condition that the previous step has finished and the current control commands have been received. Whether a step is finished or not is decided according to its step conditions. So, this model can be constructed as follows. We suppose that $C(t)$ is the combined state of all the step conditions in the t-th step. Since each condition is normally a PLC signal, marked by $c_1(t)$, $c_2(t)$…, therefore, we have:

$$C(t) = c_1(t) \cdot c_2(t) \cdot \mathrm{A} = \prod_j c_j(t) \tag{1}$$

where "$C(t)$=1" indicates that the step conditions are satisfied and the next step can be started, and "$C(t)$=0" indicates that the conditions are not satisfied and the action sequence cannot be carried out. Similarly, the step conditions of the previous step is expressed by the following:

$$C(t-1) = c_1(t-1) \cdot c_2(t-1) \cdot \mathrm{A} = \prod_j c_j(t-1) \tag{2}$$

The later steps is described as (3)~(6), eventually the condition that is not satisfied can be found:

$$I(t) = i_1(t) \cdot i_2(t) \cdot \mathrm{A} = \prod_j i_j(t) \tag{3}$$

$$F(t) = C(t-1) \cdot \overline{I(t)} \tag{4}$$

$$\overline{I(t)} = \overline{\prod_j i_j(t)} = \overline{i_1(t)} + \overline{i_2(t)} + \mathrm{A} = 1 \tag{5}$$

$$\overline{C(t)} = \overline{\prod_j c_j(t)} = \overline{c_1(t)} + \overline{c_2(t)} + \mathrm{A} = \sum_j \overline{c_j(t)} = 1 \tag{6}$$

Diagnostic Reasoning for Sequential Control Faults. Under normal operating conditions, the PLC controls the manufacturing system according to the sequence of actions. At the same time, each step in the control sequence is monitored by the watch-dog-timer in PLC. If the machine is in normal condition, it will operate sequentially according to the preset sequence. Therefore, overstaying of the machine control status at a certain action suggests the occurrence of a fault. Upon the detection of a sequential control fault, diagnosis is carried out using the knowledge about the sequential control of the manufacturing system. At first the current values of all the signals in PLC will be read. Then the start conditions of every step are analyzed according to these values, in conjunction with the control sequence. By doing so, the step where a fault has occurred can be determined. In the end, each control command and condition of the faulty step are checked, till the exact fault cause is found. Modified engine consists of three parts: a conflict generator, a hitting set tree, and the order of priority. The conflict generator takes as input part diagnosis determine whether there is a constraint violation. If so, it returns this violates assumption. These conflicts are returned to the hitting set tree, which contains the local diagnosis. Sent to the conflict part of the solution is to expand the new generator according to the result of conflict. Decision, this part of the diagnosis of dilated, the preference ordering is determined. This component reordering in the diagnosis of part of the tree based on user preference criteria, such as minimum set contains, base, or probability. If you didn't find any conflict generator conflict, part is the diagnosis. For details, see [5].

Conclusion and Summary

Manufacturing systems present an important domain of diagnostic application. The development of automated diagnostic techniques and systems can help to minimize downtime and maintain an efficient output. This is a need common to all manufacturing enterprises. The knowledge-based real-time diagnostic system is developed to meet this need. It can continuously acquire data from the PLC, identify possible faults, search for their causes and suggest corrective actions.

The problems and complexity in after-market development of such a diagnostic system have left the manufacturers of the manufacturing systems as the best people in a position to apply diagnosis effectively to their products. There are diagnostic functions available in modern PLC controlled manufacturing systems. However, they are still limited and need further development. The prospects are greater where larger investments are concerned, as the cost of a fault is higher.

This is a rapidly developing area which has attracted more and more researchers. Good results have been achieved, but there is still much work to do. From the author's point of view, future work will concentrate to: (1) refine the diagnostic knowledge acquisition methods and reasoning algorithms, so as to improve the efficiency of the diagnostic system[6]. (2) investigate models that incorporate PLC control on continuous processes of the manufacturing systems, implementing a systematic integrated methodology for prediction, monitoring and diagnosis. (3) define an embedded diagnosis system approach which will integrate the diagnostic models in the PLC's, so that faults can be diagnosed in real time.

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