Chapter 12
Automatic Timed Automata Extraction from Ladder Programs for Model-Based Analysis of Control Systems

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ABSTRACT
Control Systems are used to produce a certain result with little or no human supervision. The principal aim of such systems is to ensure that resources are used efficiently and that the desired product quality is achieved. Moreover, for critical systems such as oil and gas plants, it is important to guarantee the safety and dependability of the operation. Therefore, it is necessary to verify whether what is running in the device is in accordance with what was defined in the specification documents. The goal of this chapter is to present a method that automatically generates the timed automata models from the specification ISA 5.2 Binary Logic Diagrams, and the implementation Ladder programs, for model-based analysis, in order to increase the confidence in the behavior of critical Control Systems. This approach is based on the use of the Uppaal tool and the Uppaal-TRON testing tool.

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INTRODUCTION

The development of new technologies raised the complexity level of modern industrial control and automation systems. In order to overcome the challenge of guarantee the dependability of the process and the safety of equipments, installation and employees, new methods, techniques and tools have to be adopted (Neves, Duarte, Viana, & Lucena, 2007). Dependability means the probability that a device will function properly for a defined period of time under the influence of specific environmental and operational conditions (ISO, 1997).

In order to overcome the challenges mentioned above, verification techniques have been increasingly used in Control Systems. Control Systems (Wescott, 2006) are widely used in industries and have the following objectives: to reduce production costs; to increase the quality level of products; to minimize the material and energy losses; and, furthermore, should ensure that the program executes as expected or designed.

The usual development scenario is as follow. First, the interested company generates a set of requirements that constitute the specification. Once the specification is completed, the software company develop the software using some of the IEC 61131-3 language (PLCopen, 2004; John & Tiegellkamp, 2001). Finally, the program is compiled to run in a given Programmable Logic Controller (PLC) (Parr, 2003). It is important to note that the company does not have a formal guarantee that the final implementation corresponds to its original specification. Even considering the fact that there is an important phase of acceptance tests, it is impossible to guarantee the conformance because the number of inputs, events, timing, and their combinations.

In this context, it is essential to analyze if the system is correct. It is necessary to check whether what is executing in the device is in accordance with what is defined in the specification documents. One possibility to achieve this is executing conformance testing to validate the implementation against its specification.

The objective in this chapter is to introduce a method to increase the dependability and safety in the operation of Control Systems. The proposed method consists in the translation of ISA 5.2 Binary Logic Diagrams (ISA, 1992), for the specification, and Ladder programs, for the implementation, in eXtensible Markup Language (XML) files. These files represent the timed automata model automata (Alur & Dill, 1994; Bengtsson & Yi, 2003) in the Uppaal tool (Behrmann, David & Larsen, 2004) internal representation. After the generation of timed automata models for the specification and implementation, the conformance test is performed. These test consists of generation and execution of test cases to validate the correctness of the system. This is done using the Uppaal-TRON tool (Larsen, Mikucionis, Nielsen, & Skou, 2005).

BACKGROUND

In this section the theoretical basis necessary for the understanding of this chapter is presented. The main concepts related to ISA 5.2 Binary Logic Diagrams (ISA, 1992), Programmable Logic Controllers (PLC), Ladder and timed automata are introduced.

ISA 5.2 Binary Logic Diagrams

The ISA 5.2 standard is used to describe the specification binary systems, and aims to improve communication between parties involved in the development systems through the use of symbols that represent operations processes (ISA, 1992). This standard facilitates the understanding of the functioning of modeled system. Some of the symbols used by this standard are illustrated in Table 1.
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