

Chapter 13

Reconfiguration of Industrial Embedded Control Systems

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ABSTRACT

This research work deals with the development of safety reconfigurable embedded control systems following the international industrial component-based standard IEC61499. According to this standard, a function block (FB) is a functional unit of software and a control application a FB network that has to meet functional and temporal properties described in user requirements. We define in the book chapter a new semantic of the reconfiguration where a crucial criterion to consider is the automatic improvement of the system performance at run-time. If a reconfiguration scenario is applied at run-time, then the FB network implementing the system is totally changed or modified. To handle all possible reconfiguration forms, we propose thereafter an agent-based architecture that applies automatic reconfigurations to adapt the system according to well defined conditions and we model this agent with nested state machines according to the formalism of net condition/event systems which is an extension of the Petri net formalism. In order to satisfy user requirements, we specify the functional and temporal properties with the temporal logic CTL (as well as its extensions ECTL and TCTL) and we apply the model checker SESA to check the whole system behavior. To assign this reconfigurable system into the execution environment, we define thereafter an approach based on the exploration of reachability graphs to construct feasible OS tasks that encode the FB network corresponding to each reconfiguration scenario. Therefore, the system is implemented with sets of OS tasks where each set is to load in memory when the corresponding scenario is applied by the Agent. We developed the tool X-Reconfig to support these contributions that we apply on the FESTO and EnAS benchmark production systems available in our research laboratory.

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INTRODUCTION

Nowadays in Manufacturing Industry, the development of Safety Embedded Control Systems is not a trivial activity because a failure can be critical for the safety of human beings. According to user requirements, they have classically to satisfy functional and temporal properties (Baruah & Goossens, 2004) but their time to market has to be shorter than ever. To address all these important requirements, the component-based approach is studied in several academic research works and also in interesting industrial projects to develop modular embedded systems in order to control the design complexity and to support the reusability of already developed components (Bensalem, Bozga, Sifakis & Nguyen, 2008). In industry, several component-based technologies have been proposed to design the application (as a composition of components) (Crnkovic & Larsson, 2002). Among all these technologies, the International Standard IEC61499 is proposed by the International Electrotechnical Commission to design distributed control applications as well as the corresponding execution environment (IEC61499, 2004). In this Standard, a Function Block is an event-triggered component composed of an Interface and an Implementation. The interface contains data/event inputs/outputs supporting interactions with the environment. Events are responsible for the activation of the block, whereas data contain valued information. The Implementation of the block contains algorithms to execute when the corresponding events occur. The selection of an algorithm to execute is performed by a state machine called Execution Control Chart (ECC) which is also responsible for sending output events at the end of the algorithm execution. An IEC61499 application is a network of blocks that have to meet temporal properties defined in this contribution as end-to-end bounds (denoted *eertb*) which have on one end the input signals from sensors and on the other end the output signals to the corresponding actuators.

Today in academy and industry, rich books have been written (Lewis, 2001; Vyatkin, 2007; Marik, Vyatkin, & Colombo, 2007), many research works have been made (Vyatkin & Hanisch, 2003; Thramboulidis, Perdakis, & Kantas, 2007; Panjaitan & Frey, 2007; Khalgui, Rebeuf, & Simonot-Lion, 2007; Thramboulidis, 2005; Vyatkin, 2006), useful tools (<http://www.isagraf.com>, <http://www.holobloc.com>) have been developed, real industrial platforms (<http://www.itia.cnr.it>) have been deployed while following this International Standard and finally in our Research Laboratory at the Martin Luther University in Germany, two Benchmark Production Systems FESTO and EnAS are developed according to this component-based technology. On the other hand, the new generation of Industrial Control Systems is addressing today new criteria as flexibility and agility. To reduce their cost, these systems have to be changed and adapted to their environment without any disturbance. Several interesting academic and industrial research works have been made last years to develop Reconfigurable Control Systems. We distinguish in these works two reconfiguration policies: the static and dynamic reconfigurations where the static reconfiguration is applied off-line to apply changes before the system cold start (Angelov, Sierszecki & Marian, 2005), whereas the dynamic reconfiguration is applied dynamically at run-time. In the last policy, two cases exist: the manual reconfiguration applied by the user (Rooker, Sunder, Strasser, Zoitl, Hummer & Ebenhofer, 2007) and the automatic reconfiguration applied by an Intelligent Agent localized in the system (Al-Safi & Vyatkin, 2007).

In this book chapter, we are interested in the automatic reconfiguration of Industrial Control Systems following the International Standard IEC61499. We define at first time a new semantic of this type of reconfiguration where a crucial criterion to consider is the automatic improvement of the system performance at run-time. We propose thereafter an Agent-based architecture to handle all possible reconfiguration scenarios. Therefore,

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