Chapter 14

Dynamically Reconfigurable Embedded Architectures for Safe Transportation Systems

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ABSTRACT

Embedded system designers are increasingly relying on Field Programmable Gate Arrays (FPGAs) as target design platforms. Today's FPGAs provide high levels of logic density and rich sets of embedded hardware components. They are also inherently flexible and can be easily and quickly modified to meet changing applications or system requirements. On the other hand, FPGAs are generally slower and consume more power than Application-Specific Integrated Circuits (ASICs). However, advances in FPGA architectures, such as Dynamic Partial Reconfiguration (DPR), are helping bridge this gap. DPR enables a portion of an FPGA device to be reconfigured while the device is still operating. This chapter explores the advantage of using the DPR feature in an automotive system. The authors implement a Driver Assistant System (DAS) based on a Multiple Target Tracking (MTT) algorithm as the automotive base system. They show how the DAS architecture can be adjusted dynamically to different scenario situations to provide interesting functionalities to the driver.

INTRODUCTION

Embedded applications in transportation systems are becoming increasingly complex, and new applications have emerged to respond to people and societal needs and to ensure driver and passenger safety. Applications such as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) communications, in-vehicle infotainment, and assistance for elderly and disabled drivers require powerful

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processing and communication capabilities. Moreover, modern transport tools play the leading role in strategically worldwide projects such as green and sustainable mobility in future smart cities. To fulfill these tasks, the number and types of sensors in next generation of transport systems will continually increase. This requires significant computing power, low energy consumption and high reliability.

At the technological level, advances in microelectronic fabrication technologies have resulted in a proliferation of electronic and micro-electronic devices in automotive systems. While early electronic control units (ECUs) were mainly used for engine and transmission control or simple cabin control functions, contemporary ECUs are used in a wide range of applications including audio and video entertainment, navigation and trip planning, communications and networking, passenger safety, and driver assistance.

Driver assistance systems (DAS) are an increasingly important class of automotive applications, particularly in commercial vehicles where they can greatly reduce a driver's workload and improve road safety in stressful driving conditions such as at night or in bad weather. Driver assistance systems commonly require real-time monitoring of the driving environment and other vehicles on the road. The availability of low-power automotive radar systems makes it possible to track the speed, distance, and relative position of multiple obstacles, called targets through the chapter, in the radar's field of view. Such Multiple-Target Tracking (MTT) functions are crucial for driver assistance applications such as collision avoidance, intelligent cruise control, or automatic parking.

As the driving conditions and environment change, the type of processing required for MTT also changes. In this chapter, we show how the functionality and accuracy of Driver Assistant Systems (DAS) can be automatically tuned to match the dynamics of moving obstacles on the road. We show how dynamic partial reconfiguration (DPR) can be used to free hardware resources for other uses, such as tracking more obstacles, accelerating other computational functions, or reducing power consumption.

We also demonstrate how the accuracy of the filtering blocks can be dynamically and automatically tuned to match the characteristics of the operational environment. This contrasts with prevailing approaches to dynamic reconfiguration, which are mainly demand-driven.

In this chapter, DPR is used to adapt the MTT embedded system architecture according to driving conditions in the two following scenarios:

1. **Obstacle Density:** The computational needs of a MTT system increase with the *number of targets* that must be tracked. When the environment changes from, say, open highway to narrow city street, higher levels of accuracy in the obstacle position calculation are needed to track multiple, potentially closer targets. Conversely, when the driving environment changes from dense to sparse, the accuracy of the filter can be reduced to minimize resource utilization and energy consumption. We also demonstrate the ease with which we can switch between hardware implementations automatically using a simple heuristic.
2. **Obstacle Positions:** When targets move *closer to the radar*, they should be tracked at higher levels of accuracy since they can potentially become more hazardous. On the other hand, when targets move further away, less accurate tracking (filters) can be used. The functionality and accuracy of an MTT system can be automatically tuned to match the dynamics of moving obstacles on the road. To support efficiently obstacles at *different distances*, three filters are used in different configurations to support different driving scenarios (Far, Medium and Close). These filters include a Kalman filter for angle estimation (KFA), a Kalman Filter for distance estimation (KFD) and an extended

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