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Sensor data fusion in the context of electric vehicles charging stations using a Network-on-Chip

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ABSTRACT

This paper presents a platform for evaluating sensor data fusion algorithms based on a Network-on-Chip (NoC). Initially the NoC is simulated by MPSoCSim, which contains an ARM and several MicroBlaze processors. The approach is furthermore evaluated on a real FPGA system in an automotive context. Charging stations for electric vehicles consist of expensive sensors, as the energy measurement system is an important part used for billing purposes, for safety of the charging process and for security. The sensors, that are usually used, are special made solutions, which are thermally stable and highly accurate. The NoC infrastructure presented in this paper results in a new method for sensor data fusion, which decreases costs by using inexpensive sensor units. These sensor units are sensitive to temperature changes. The target of the sensor data fusion approach is to replace expensive sensors with inexpensive ones without loosing accuracy. The presented simulation platform allows an easy exchange of sensor models and sensor data fusion algorithms.

1. Introduction

In recent years, electric mobility is getting more important, because of the scarcity of resources and environmental pollution. Therefore, the German government has the target to bring about 1 million electric cars on German roads by 2020 [1,2]. This fast-growing number of electric vehicles leads to the need for rapid development of the charging infrastructure. Thereby, the number of charging stations for electric vehicles should rise fast. In this paper, a simulation environment is presented, for supporting the development of energy measurement systems based on FPGAs for use in charging stations. Furthermore, the results of the presented simulation environment are compared with the results of the universal energy measurement system presented in [3] and evaluated on a real FPGA platform based on a Xilinx Zynq System-on-Chip (SoC). The energy measurement system is an important part of the electric vehicle charging station. It fulfils several tasks e.g. energy measurement for billing purposes or supporting fast error detection option with in the charging process.

There are some requirements for such a simulation environment for complex energy measurement systems. The first requirement is the possibility to process the values of several measuring sensor units simultaneously. This is important, because there are several currents and voltages at various points to be measured. In this way the electrical safety of the charging station is increased. The second requirement is the ability to perform data processing in parallel. By parallelised processes the efficiency of the energy measurement system is increased. A further requirement is the ease of portability of the implemented simulation algorithms in real hardware. In this way the period to develop the energy measurement system is reduced. Another requirement is the reconfigurability of the different algorithms during operation. Thus, new conditions can be made effective without having to initiate a restart or interruption of the operation.

This paper presents a new technique for the simulation of sensor data fusion algorithms using MPSoCSim [4], which extends the paper presented in [5]. Furthermore, a physical development system is presented that uses the insights of the simulation phase. The approach allows replacing accurate expensive sensors by multiple less expensive and less accurate sensors. Consequently, the overall cost of the system is decreased. The NoC infrastructure furthermore enables simultaneous processing of sensor data. Due to simulation, changes in the algorithms can be performed at early stages of the development cycle, resulting in a shorter time to market.

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Within the next sections the proposed simulation environment is described in more detail. Section 2 introduces some related works first. The following Section 3 introduces the simulator for heterogeneous Network-on-Chip-based (NoC) Multiprocessor Systems-on-Chip (MPSoCs). In Section 4, a description of the measurement system and the important part of the charging station is done. In Section 5, the implementation of the simulation environment and the physical hardware is presented. The results of the environment implementation are introduced in Section 6. Finally, this article finishes with a conclusion.

2. Related work

There is a lot of research about the charging stations and particularly the measurement system recently. In [6] a bi-directional smart metering system for electric vehicles is presented. For the smart metering a multifunctional single chip solution is used, which does the measurement and also computes the consumed energy. This system supports only two sensors simultaneously, which is not enough for the idea with sensor fusion. In yet other studies [7–9] the presented systems are for managing information of charging stations or for power monitoring and control. The aim of these systems is not only to measure the charged energy but also to gather information about the quality of the signals. With this additional information the systems help to manage e.g. charging pattern or smart grids. All these systems do not make sensor data fusion.

Sensor data fusion combines the measurements of multiple sensors to decrease uncertainty of the individual sensor. In this manner, a wide variety of applications such as robotic [10], automotive [11] and radar [12] benefits from sensor data fusion.

For all of these applications, a lot of different approaches for sensor data fusion exist. The approach presented in this paper is evaluated using a real FPGA system containing a Network-on-Chip. To the best of the authors knowledge none of the above mentioned projects used a real system to verify the simulation results.

In [13] and [14], a power-efficient and architectural concept is introduced for cross-domain mixed-critical systems with safety requirements. The aim of [13] and [14] is to build a comprehensive suite of analysis, simulation and verification tools for such system. Furthermore, hardware and software reference platforms that assist the implementation are planned. This project focuses on improving the power efficiency of systems using optimised MPSoCs. In comparison to our approach, a virtual platform is also used to analyse the system behaviour. However, the main focus of this work is a platform that optimises the accuracy and cost using sensor fusion. The work presented in [15] explains a virtual platform-based software testing and debugging approach for NoC-based MPSoCs. Processing Elements (PE) are also simulated by Imperas Open Virtual Platform (OVP) and connected by a virtual model of the Nostrum NoC [15]. A synchronous system execution is provided by means of a synchronisation signal, called HeartBeat. The OVP simulation environment takes care about the synchronisation in our approach. Therefore, no additional synchronisation signal is implemented. In general, the synchronisation of different software approaches can lead to a performance bottleneck. Moreover, the system in [15] is evaluated by image processing algorithms. Our approach combines sensor fusion with modern MPSoCs.

3. MPSoCSim

MPSoCSim is a simulator for heterogeneous Network-on-Chip-based (NoC) Multiprocessor Systems-on-Chip (MPSoCs) [4] developed by the application-specific Multi-Core Architectures (MCA) group at the Ruhr-University Bochum. The main contribution of MPSoCSim is to provide a flexible and fast simulation framework for NoC-based MPSoCs targeting real hardware implementations. Thus verification of an MPSoC design at an early design stage is possible. The capability of MPSoCSim to simulate actual hardware designs has been shown in [4]. Here, the simulator is compared to RAR-NoC [16], a NoC-based MPSoC implemented on a Xilinx Zynq device.

3.1. Structure of the simulator

The MPSoCSim simulator extends the OVP processor models with a SystemC-based NoC infrastructure. OVP is developed by Imperas and provides performant processor models [17]. Among these, the models of the ARM processor and the Microblaze softcore processor are of specific interest for MPSoCSim, as these models finally allow the comparison of simulation and hardware implementation on a Xilinx Zynq device. Within MPSoCSim, the OVP processor models are organised in separated local groups. Each local group represents a processing element featuring a local bus for communication. The local bus is connected to a network interface, which then handles the communication of the PE with the attached NoC (Fig. 1). For a better understanding of the context of this article, the internal structure of the simulator is presented next. The memory (RAM), located within the local group, can be used to exchange data amongst processing elements inside the simulated network. It is used for the evaluation of the presented concept, as data of simulated sensors is distributed to distant processors and stored inside the RAM. Furthermore, a timer is implemented to extend the simulation statistics. The timer informs about the current simulation time even during runtime. In this work, MicroBlaze processors have been used to model voltage and current sensors. Using these MicroBlaze processors allows an easy exchange of sensor models

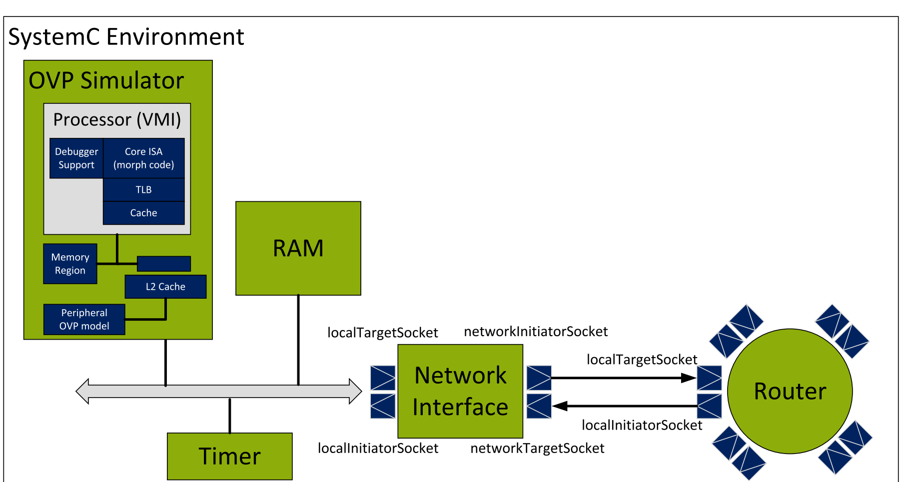

Fig. 1. Local group of MPSoCSim containing the processor model, a memory, timer and the network interface.