The EMC² Project on Embedded Microcontrollers
- Progress After Two Years -

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***Abstract*—EMC² stands for "Embedded Multi-Core Systems for Mixed Criticality Applications in Dynamic and Changeable Real-Time Environments". The project is meanwhile running for two years. This paper provides recent progress on technical work in the different workpackages and use cases. Major progress in the research on system architecture, design methodology, platform and operating systems, and in qualification and certification are reported. Application cases in the fields of automotive, space, and industry are presented exploiting the technical results achieved.**

Keywords—Mixed criticality, dynamic application, real-time applications, multitasking, multicore, embedded microcontroller, open system, integrated toolchain

I. Introduction

The EMC² project focuses on the industrialization of European research outcomes and builds on the results of several previous Artemis, European and National projects. It contributes to the goal of maintaining Europe's excellent position in embedded systems.

The project has 100 ordinary partners and one associated partner. They come from 16 European countries with Austria, Germany, the Netherlands, Sweden and Spain being the strongest stakeholders. The project has a budget of € 90 Mio with € 40 Mio funding.

The following elements are central to develop inherently safe and cost-efficient cyber-physical systems using modern microelectronics

- Handling of mixed criticality applications under real-time conditions in one piece of hardware (most important)
- Dynamic Adaptability in Open Systems
- Utilization of expensive system features only as Service-on-Demand in order to reduce the overall system cost.
- Full scale deployment and management of integrated tool chains, through the entire lifecycle
- Handling of a variable number of control units in one system

The EMC² embedded system approach will force the breakthrough for the deployment of multi-core technology in professional application domains – Avionics, Space, Automotive, Medical, Energy, and Industrial factory automation – where real-time and mixed-criticality are an issue. The project organization follows a matrix structure with horizontal and vertical activities closely linked to each other. Technology–related workpackages complement dedicated Living Labs from various application domains representing European major industry sectors.

- Horizontal activities: Technological work packages develop dedicated technologies required for the implementation of embedded, mixed-criticality multi-core systems.
- Vertical activities: So-called living labs include several demonstrators for mixed-criticality embedded systems aiming at the same application domain. The Living Labs apply and evaluate the results of the technology work packages in dedicated use cases.

Technology developments strictly follow the requirements derived from the specifications defined in each application domain. Their results are then fed back to the development of demonstrators on application level. As a joint effort of technology work packages and application innovation work packages EMC² provides a flexible microprocessor System on Chip architecture that can be tailored by middleware to the needs of a particular application domain. This will substantially reduce the non-recurring development costs and the time to market of new embedded system applications and significantly cut the recurring cost of the respective products. Driven by the application needs EMC² puts a strong focus on re-configurability and adaptability.

The project is providing reference designs and architectures that present solutions to key technical challenges – such as networking, security, robustness, diagnosis, maintenance, integrated resource management, self-organization, and – most notably – dynamic adjustments in changing systems.

Such a huge project can only be organized with a strongly decentralized management structure. Only certain key functions such contractual issues, reporting, inter-WP relations and external representation are kept centralized while most of the technical developments are handled in smaller working groups along specific value chains. EMC² project workpackages follow unique objectives, task descriptions, deliverables, milestones, time plan etc., fitting seamlessly into the overall EMC² plan.

In the next sections, we present technical results achieved in the EMC² project after about two years of execution. We start with results from the technical workpackages and continue on showing demonstrators from the living labs.

II. RESULTS OF TECHNCIAL DEVELOPMENTS

In workpackages 1-6 the technical foundations are laid for the implementation of embedded microcontrollers into the various applications. As of the end of the second year in EMC2 important elements of the service-oriented architecture are implemented for the multi- core networked systems. Mixed critical applications were modeled in the work on application programmability models.

The design methodology was verified in the Quadcopter use case. Benefit of dynamic criticality was demonstrated and source code check accomplished in the verification tool.

The internal validation of the WP2 approach for modelling and a systematic refinement process has proven its applicability. Now it is ready for use and test in other technical and application oriented workpackages.

In the work on dynamic runtime environments and services, mechanisms were defined on communication services, virtualization and isolation, security mechanisms and services, and safety and real-time. Platform and operating systems extension were implemented allowing and exploiting dynamics to improve platform performance and resource utilization.

In the system qualification and certification work an integrated approach for Safety&Security Co-Engineering was conducted. The corresponding tool-support was implemented and an integrated approach for Safety&Security Co-Engineering was realized. Furthermore, conditional runtime certificates are set up supporting horizontal (app to app) and vertical (app to platform) dependencies. Thus, Safety (and Security) Assurance and Certification in EMC²-Systems are enabled.

In the following, examples are presented in application areas of Automotive, Space, Industry, and Cross Domain Applications.

III. AUTOMOTIVE

Partners Volvo and LTU develop a service-oriented architecture for embedded truck architecture. They consider the vehicle as a service in a larger application domain, or as a multi service provider: each potential in-vehicle software element is considered as a service. These functionalities in form of services are orchestrated at design/runtime and are aware of the available real-time resources.

Partners merge multiple ECUs and thus reduce the hardware costs, and separate software components of different criticalities, e.g. safety or security. Here the ultimate goal is to better utilize hardware resources. Volvo has furthermore, developed methods and tools in cooperation with DTU to partition, allocate and schedule software on multi-core control units (Fig. 1).

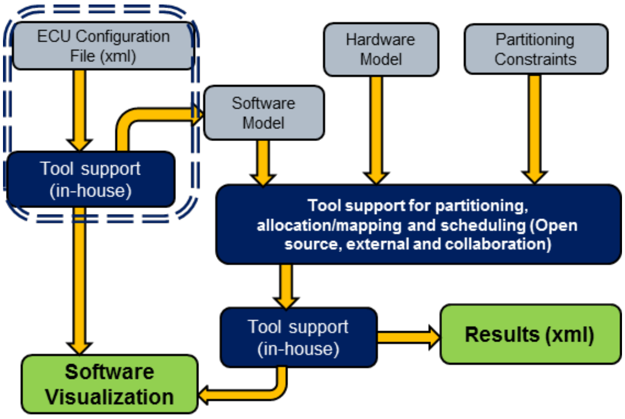

Fig. 1 Overview of tool for partitioning, allocation and scheduling of SW on multi-core control units

IV. SPACE

Partner TASE implements an MPSoC image processor based on CCSDS 122 & 352 standards for data encryption based on OpenMP paradigm. CCSDS 122 standard for image compression based on OpenMP paradigm is partially implemented. Discrete Wavelent Transform is used here. The system is validated on a Multicore architecture (ARM Quad-Core) (Fig. 2).

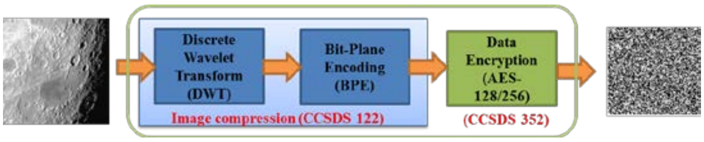

Fig. 2 Flow diagram of image processor with encryption

V. INDUSTRY

ITI from Valencia works on Quality Control by 3D Inspection. They compare sequential and parallel models for a task of 3D object reconstruction. They have meanwhile modelled two software flows, representing the sequential and the parallel execution tasks. An analysis of the computed response time for both flows was executed with the “art2kitekt” tool suite. A multicore execution platform was modeled to host the task set software models. Parallel processes were optimized to perform as fast as possible on a virtual multi-core execution platform (Fig. 3).

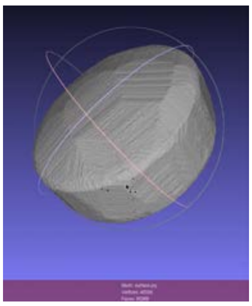

Fig. 3 3-D object under investigation

VI. CROSS DOMAIN APPLICATIONS

In the seismic Processing usecase WesternGeco, Simula and Fornebu implement an automated MATLAB to plain C++ code translator. They decompose and interpret the MATLAB syntax, provide context-sensitive translation rules and show examples & documentation. They thus generate a semi-automatic low-level and hardware-efficient code of seismic processing from high-level Matlab models (Fig. 4)

Fig. 4 Reflected waves from shock events illustrating the huge amount of data provided in these kinds of experiments

In the video surveillance use case eVision, SevenSolutions, and Siemens want to accelerate an object (face) detection algorithm by using multi-core or FPGA architectures. The single steps achieved towards this goal are

- Avoid the use of dynamic memory allocation.
- Reduce memory requirements.
- Convert floating point arithmetic to fixed point.
- Convert recursive loops into iterative ones.
- Re-design algorithms to work in a FIFO architecture.
- Adding Memory controller to FPGA board

Brno university provides a computer vision system for cars that implements an object/license plate detector in Xilinx Zynq and conducted further experiments with Random Forests for object detection (Fig. 5).

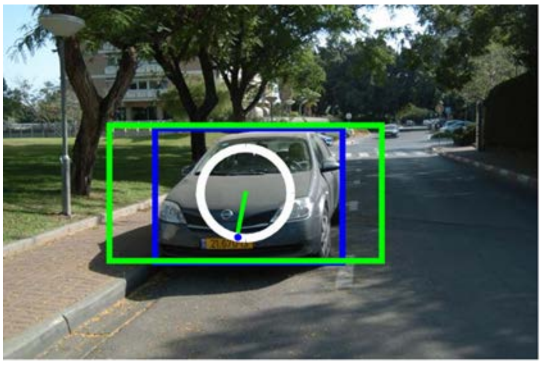

Fig. 5 Random forest vehicle detector providing also orientation of the vehicle

VII. CONCLUSION

The project is in its deep technical workphase. The work is on track and is planned to finish as scheduled.

Looking into the future, after termination of the EMC^2 project, several important questions will remain unsolved due to the limited duration of three years for this project. The most important question remaining open regards standardization. There is high demand for standardization in these professional areas although the preconditions in areas like automotive, avionic and industry are rather different. We are convinced that an ongoing effort for providing a standardized platform can be of major benefit for the European industry.

Furthermore, we expect the formation of new smaller consortia conducting new product-oriented and funding-related projects in specific areas. EMC^2 being a large platform project provides the ideal basis for such development catalyzing these new groups to the benefit of European industry and research.

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REFERENCES

[1] EMC^2 public Webpage: http://www.artemis-emc2.eu/