EMC² workshop @Artemis Technology Conference 2016

October 6th, 2016

1. Morning session

9:00-9.30 Overview of EMC² project – achievements and challenges (Werner Weber)

9.30-10:00 System Architectures (Andreas Eckel)

10:00-10.30 Multi-core Hardware Architectures and Concepts (Rolf Meyer replacing Rainer Buchty)

10.30-11:00 Coffee break

11:00-11.30 Executable Application Models and Design Tools for Mixed-Critical, Multi-Core Embedded Systems (Albert Cohen)

11:30-12.00 EMC² towards standardization (Erwin Schoitsch)
2. Afternoon session

13.30-14:00 Demo by Volvo (Thomas Söderqvist and Atul Yadav)

14.00-14:30 Real Time Concept Prototyping and Validation of Functional Safety Certification Test Measures by FPGA platform (Zuhal Clarke)

14:30-14.50 Carrier Under Carrier Interference Detector (Javier Valera)

14.50-15.10 Industrial manufacturing and logistics (Juha Kuusela)

15:10-15.30 Internet of Things (Yudani Riobo)
ARTEMIS 2013 AIPP5

EMC²
A Platform Project on Embedded Microcontrollers in Applications of Mobility, Industry and the Internet of Things

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Project Overview

Numbers

Embedded Multi-core Systems for Mixed-Criticality Applications in Dynamic and Changeable Real-Time Environments – EMC²
(Artemis Innovation Pilot Project (AIPP))

- AIPP 5: Computing Platforms for Embedded Systems
- Budget: 93.9 M€
- Funding: 15.7 M€ EU funding (Artemis)
  26.7 M€ National funding
- Resources: 9636 person months (803 person years)
- Consortium: 101 Partners (plus 1 associate partner)
- From: 16 EU Countries

⇒ Largest ARTEMIS-JU project ever!
most relevant EU players on board
Project Overview
European Dimension

% of total costs per country

- FR
- AT
- BE
- CZ
- DE
- DK
- ES
- GR
- IRL
- IT
- LAT
- NL
- NO
- PO
- SE
- UK
Technological Productivity

Microprocessor Transistor Counts 1971-2011 & Moore's Law

Doubling of transistor count every two years
“We live in a world where function (hardware and software) is described in code. But code does not scale. **Individual coders cannot code more lines of code than they could decades ago.** And as the projects get bigger, productivity actually decreases: One engineer can code about 10,000 lines of (debugged, production-ready) code in a year. But 100 Engineers cannot code 1,000,000 lines of (debugged, production-ready) code in a year“...

“...The functionality of the 30 lines of code (per engineer-day) has increased very slowly over time, and most of this increase has been due to the use of libraries and IP. The introduction of C++ in 1983 also gave software productivity a small, one time gain.“
Motivation for EMC2

- Very fast technological advances of μ-electronics in past decades
- Amazing capabilities at lowered cost levels
- Today primarily exploited in consumer-oriented products
- Systems quickly put together since the next technology generation is already waiting around the corner
- Errors may be tolerated and a new execution attempt started
- This (and similar) way(s) of handling errors acceptable for consumer products
Application innovation

- In professional areas the consumer approach is not feasible: **Automotive, Avionics, Space, Industry, Health care, Infrastructure**
- Need much higher level of operational reliability
- Higher HW/SW complexity
- Have to fulfill real-time safety requirements
- Dynamic reconfiguration during runtime
- Prime task of EMC² to bring two worlds together
  - Consumer world: use of advanced µC systems
  - Professional world: reliability, complexity, real-time
Technological innovation

- Mixed Criticality
  - Handle applications with different priorities
- Dynamic Re-configuration
  - Full range of dynamic changes on application level
- Hardware Complexity
  - Variable number of control units at runtime
EMC² - Embedded Multi-core Systems for Mixed-Criticality Applications in Dynamic and Changeable Real-Time Environments

Applications: Automotive, Avionics, Space, Industry, Health care; Infrastructure

Improve performance, lower cost

Improve energy efficiency
Model based Design for MC Systems

Goal: Safe optimization of QoS in Mixed-Critical Applications

Use-case Avionic Control and Payload Platform for Multi-Rotor Systems

- Safety critical System
  - 3 parallel Flight Control Tasks (2 ms)
  - 6 Sensor Channels (2-30ms)
  - 3 Sensor Compute Tasks (2 ms)
  - Small violations accumulate to crash

- High Throughput Video application
  - Mission critical object detection
  - Minimal 6 frames/second
  - Demand for high data throughput

WP2
Optimized QoS in Mixed-Critical Applications with Dynamic Criticalities

**Static schedule (WCET based)**

Before

<table>
<thead>
<tr>
<th>Flight CS</th>
<th>Video Proc: 300x200 px.</th>
</tr>
</thead>
<tbody>
<tr>
<td>104 ms</td>
<td>58 ms</td>
</tr>
<tr>
<td>167 ms frame</td>
<td></td>
</tr>
</tbody>
</table>

Dynamic Criticality Modes

After

95% (typical case) Flight CS: 64 ms
Leaves: 103 ms or 460x320 px.

<table>
<thead>
<tr>
<th>Criticality Policy</th>
<th># Degraded</th>
<th># Full Quality</th>
<th>Av. Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>30</td>
<td>0</td>
<td>1055 Kib/sec</td>
</tr>
<tr>
<td>Dynamic</td>
<td>13 (±3)</td>
<td>17(±3)</td>
<td>1923 Kib/sec (182%)</td>
</tr>
</tbody>
</table>

Frank Oppenheimer, OFFIS
Dynamic runtime environments and services

- Various advanced mechanisms (~80) enabling
  - handling high congestion in networked systems
  - e.g. in cooperative intelligent transportation system (ITS) with wireless sensor networks
- Mixing different criticality domains in networks for performance and high integration
  - automotive Ethernet networks
  - networks-on-chip
Isolation between safety critical parts and user domain

- Improving security
- Inter-core communication
- Reduced Power Consumption

Advanced Virtualization and Isolation Mechanisms

Source: Lars Völker, BMW AG
Objective: Exploration of novel Time-of-Flight (ToF) 3D imaging concepts targeting multi-cores and mixed-criticality

Key achievements

- ToF / RGB sensor fusion
  - First time high-performance sensor fusion solution for embedded systems achieved
  - Upscaled resolution, increased sharpness, less noise, less motion artifacts, high Frames per second

- HW-accel. ToF processing
  - Novel Zynq-based system solution for mixed-critical app.
Digitalization of Software Engineering, Why?

BUG

PATCH
Digitalization of Software Engineering, Why?

BUGFIXING with high CRITICALITY, because the “Bugfix” destroyed the derailer  

BUG FIXED at least to some degree
The result of the bugfixing was:

One problem is fixed, another one is created.

This looks like software engineering…

[Herman Veldhuizen, during its way from Norway to Tibet]

Source: http://www.hermanveldhuizen.com/wp/?p=141
Digitalization of Software Engineering

**Context**
- Software development with a high focus on time-to-market
- Time is therefore critical and the test-team is always overloaded

**Problem**
- How to verify 258 bug fixes provided with the last software version?
- There is not enough time to re-verify all of them.
- Which bug fixes could be ignored safely?

**Solution**
- Use the big-data approach and calculate a *criticality-factor* for every bug fix which reflects the complexity of every bug fix.
- The higher the *criticality-factor* the higher is the probability that a new bug might have been introduced.
- Bug fixes with relatively low *criticality-factors* could be ignored, i.e. they do not need to be re-tested by the test team.
Details of the Solution

1. Analyze the complete Software data base under development, by:

1. Count the number of change operations (commit/check-in) for every single bug-fix \(<c>\)

2. Count the number of different developers involved \(<n>\)

3. Count the number of different software modules which had been changed \(<s>\)

2. Multiply all this numbers listed above, like:

\[
\text{criticality-factor} = c \times n \times s
\]

Recursively through the complete software structure, which could be several million lines of code
Cyber Physical Systems

- Important trend across application domains
- Huge potential for new applications and business

But there are significant challenges ahead that might be show stoppers:
- Safety
- Security (for Safety!)
- Adaptability, dynamic system evolvement and re-configurability over lifetime

Cf. "Umsetzungsempfehlungen Zukunftsprojekt Industrie 4.0"
Application Topics in EMC2

- Automotive
- Avionics
- Space
- Industrial manufacturing
- Logistics
- IT-infrastructure (‘Internet of Things’)
- Healthcare
- Railway
- Seismic surveying
Reduce Number of Control Units
Save cost and increase performance

Many heterogeneous single-core systems, specialized for the individual criticality levels

Multi-core systems for mixed criticalities

Vision

Aggregate resources
In multi/many cores, ECU networks

Offer system properties as services and not as independent systems
**Objective:** SoA for embedded truck architecture

- Vehicle as a service in larger application domain, or Multi service provider: each potential in-vehicle software element as a service
- Functionalities in form of services orchestrated at design/runtime
- Resource aware services for realtime systems
Multiple OS support and virtualization

**Objective:** Multiple OS support and virtualization

- merge multiple ECUs and reduce hardware costs
- separate software components of different criticality, e.g. safety or security
- better utilization of hardware resources

**Key achievement**

- Prototype of Embedded Linux and AUTOSAR running within the same MCU using the open source Xen Hypervisor (HW Dual Core ARM A7)
Objective:
Since certification authorities have concerns on mixed-critical applications on MCPs, the goal is to implement a safety net for the MCP, mitigating unforeseen or undesirable MCP operation using SW Hypervisor that monitor the MCP. Based on this information the monitor will decide if the MCP operates in normal conditions. In case of abnormal behaviour of the MCP the monitor can warn the pilot that the system is no longer operational.

Results:
No functional interference between partitions;
Bounded temporal interference (<4%) of one faulty partition on the other fault-free one.
Good separation thanks to HW watchdog + virtualization.
Hardware features to guarantee bounded quality of services are needed.
**Objective:** Enable Multicores for use in safety critical avionics applications

**Key achievements**
- **External & Internal Monitoring of MC Activities**
- **Dynamic runtime techniques** to control multicore behaviour and timing of critical tasks

Use-case **Helicopter Terrain Awareness and Warning System** will be implemented using Monitoring & Pacemaker technology
Avionics

Two **Monitoring & Pacemaker** approaches implemented:

- **External monitoring and control** by a separate hardware for highly critical avionics systems. The external hardware monitors the main multicore system and provides extra functionality in case of a complete failure of the main multicore.

- **Internal monitoring and control** by enhanced system software support. The internal approach saves the extra hardware (costs, weight and space) and allows more fine-grained control.

Both approaches show advantages and disadvantages which are evaluated.
**Objective:** Heterogeneous time-triggered architecture implemented on a hybrid MPSoC platform

**Key achievements:** Architecture hardware definition
- Time-triggered Network-On-Chip
- Trusted Interface Subsystem
- Trusted Resource Manager
Objective: MPSoC image processor based on CCSDS 122 & 352 standards

Key achievements:
Implementation of CCSDS 352 standard for data encryption based on OpenMP paradigm

Partial Implementation of CCSDS 122 standard for image compression based on OpenMP paradigm
Discrete Wavelet Transform

Validation on a Multicore architecture (ARM Quad-Core)
Objective:
Comparison between sequential and parallel models for a task of 3D object reconstruction. Object reconstruction used to distinguish different objects and to find surface defects based on texture comparison.

Key achievements:
Increased overall inspection performance by 300%: With OpenMP parallelization and an execution platform composed of 2 processors, 16 cores and multithreading capabilities a reduction of computation time from 24.563 milliseconds to 7.996 milliseconds is achieved by exploiting coarse parallelism and thus decreasing latency.
Objective:

- Design and implement an accurate, fault tolerance and reliable timing system distribution for usecase ‘Synchronized low-latency deterministic networks’

Key achievements

- Synchronization accuracy <1ns based on enhanced PTP protocol.
- Ethernet traffic with low latency and high determinism
Synchronized low-latency deterministic networks

Key achievements

- Timing Scalability (Fig. A)
  Signal propagation jitter is always under 250ps in all nodes

- Dependability features (Fig. B)
  Low-cost redundant implementation
  Single point of failure avoidance
  Able to recover from a failure with ~zero-recovery time.

Fig A: Timing scalability jitter and QoS test using a daisy-chain setup with White Rabbit

Fig B: Heterogeneous Time distribution with White-Rabbit and IRIG-B in a daisy-chain setup and a redundant HSR ring
Seismic processing

Purpose: Produce images of geological features and their structure below the surface of the earth

On sea:

- Networked computers
  - In the streamers > 2 000 computers
  - Onboard the ship > 200 computers
- Compute power > 2 Tflops
- Number of sensors > 200 000
- Huge Data rate 1-3 Gbit/s
- Disk capacity > 100 Tbytes
Seismic processing

Real-time processing on sea:
- 300 Mbit/sec per streamer
- Seismic volume
- Real-time signal processing

On ship:
- Further seismic processing

On land:
- Further seismic processing

200 computers with 4 000 cores
- 8-14 streamers behind ship
- Streamer length 10km - 14 km
- 100 - 200 computers per streamer
- 200 000 sensors per streamer
Potential impacts on Seismic Processing at sea and on land

- **Reduced engineering time:**
  New algorithms exploiting multi-cores can be implemented much faster.

- **Reduced execution time:**
  Reduced execution time translates into **reduced costs** for seismic processing.

- **Achievement 2016 Q1:**
  For the first prototype, the generated C++ code runs **2-4 as fast** as the MATLAB code.
Video surveillance for critical infrastructure

- **Video applications** are entering into more and more markets such as:
  - Surveillance
  - Medical applications
  - Automated driving
  - Quality control in production
  - Automatic access control

**Objective:** Acceleration of an object (face) detection algorithm by using multi-core or FPGA architectures.

**Achievements:** Implemented object/license plate detector in Xilinx Zynq
Experiments with High Dynamic Range detection of license plates
Further experiments with Random Forests for object detection
**Purpose:** Advanced diagnostic MR Imaging

**Challenge:**
Prevent patient call back for complex diagnostic procedures

Workflow before EMC² (state-of-the-art)
Challenge:
Prevent patient call back for complex diagnostic procedures

Workflow after EMC² (innovation)
**Objective:** Go from separate tasks deployed on separate systems to a single system solution

- **Day 1:**
  - MRI Scan Room: Scan and Acquire Image Data
  - Lay still and be patient
  - UI & Control Previewing

- **Day 2:**
  - Post-processing Image Data and Preview
  - Reconstruction
  - Postprocessing
  - Review and Report
  - Review and Report
  - Archiving
  - Viewing

Medical imaging
Fault tolerant platform, a common base for railway applications (mainline & urban)

Objectives:

- Extend programming models to better exploit multicore resources
- Extend hardware health monitoring for multicore
- Use TAS Platform in a virtual environment Pike OS Hypervisor
**Railway applications**

**Key achievements:**

- Classification of parallelization techniques for safety-critical applications
- First implementation for health monitoring (memory testing)
- First prototype running on virtualized environment (PikeOS)
Work Plan

Milestones
Technology Subprojects (WP1-WP6)

Milestones
Living Labs (WP7-WP12)

Common milestones

Project phases

requirements, concepts
specifications
1st evaluation
designs
1st innovation cycle
existing technology
integration
2nd evaluation
2nd innovation cycle
integration
final eval.

1st year
2nd year
3rd year
1st Review
2nd Review
Final Review
Project monitoring: Milestones MS1, MS2, MS3 achieved

Project running according to plan; all milestones achieved; very good results at first and second review; now working towards final results.
Public project website

- First version online at project start: www.emc2-project.eu
- New and significantly extended version online since beginning of July 2014: www.artemis-emc2.eu
- Website is updated whenever news, events and other information for publication becomes available (latest update after finalization of the 2nd EMC² Newsletter)