



ALMARVI

“Algorithms, Design Methods, and Many-Core Execution Platform for Low-Power Massive Data-Rate Video and Image Processing”

Project co-funded by the ARTEMIS Joint Undertaking under the

ASP 5: Computing Platforms for Embedded Systems

ARTEMIS JU Grant Agreement n. 621439

D6.5 – Progress Efficiency Report-2

Due date of deliverable: September 30, 2015

Start date of project: April 1, 2014

Duration: 39 months

Organisation name of lead contractor for this deliverable:

Philips

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Version number: 0.1

Submission Date: 24-May-2017

Doc reference: ALMARVI D6.5 progress efficiency report-2

Work Pack./ Task: T6.1

Description: A short summary of project progress
(max 5 lines)

Nature:	R		
Dissemination Level:	PU	Public	X
	PP	Restricted to other programme participants (including the JU)	
	RE	Restricted to a group specified by the consortium (including the JU)	
	CO	Confidential, only for members of the consortium (including the JU)	

DOCUMENT HISTORY

Release	Date	Reason of change	Status	Distribution
V0.1	24/05/2017	First draft	Draft	project
V1.0			Final	Artemis

Table of Contents

Executive Summary	4
1. Introduction	5
2. Management	6
2.1 Status of GA and PCA	6
2.2 Payments to partners	6
2.3 Issues per partner.....	6
3. Communication	7
4. Technical work	9
4.1 Deliverables.....	9
4.2 Open meetings.....	10
4.3 Publications	11
5. Conclusions	17

Executive Summary

This report summarises the major achievements of the ALMARVI project in different research, scientific, and industrial forums within the complete project period. This is in tabular form summarising the achievements of different project partners in terms of publications, workshops, special sessions, press releases, etc. It extends D6.4: progress efficiency report-1.

1. Introduction

This document gives an overview of the progress of the Almarvi project. In general, the project acts according to plan, and there were no unrecoverable issues.

2. Management

2.1 Status of GA and PCA

Table 1: Contract documents

Document	Date signed by project partners	Date signed by JU
GA		March 3, 2014
PCA	September 10, 2014	
Amendment 1		July 10, 2015
Amendment 2		January 6, 2017

2.2 Payments to partners

No issues. All payments are according to plan.

2.3 Issues per partner

Table 2: Title of Table

Partner	Date/Period	Issue	Action
Vector Fabrics	May 2016	Went bankrupt	Distribute Vector Fabrics effort over TU Delft and TU Eindhoven. Move WP4 leadership to TU Tampere
Nokia	January 1, 2015	New legal name	Distribute Nokia effort over old and new entity in first Amendment
UTIA	First 9 Months	Walnut harvesting case study is a surveillance application, but the power requirements are similar to the mobile case	Keep it as a surveillance case
Turkey's partners	Complete period	Difficulties to come to project meetings because of visa issues. Several times a visa was issued on the last day before travelling.	Ask Artemis to provide statements towards Embassies in Turkey on involvement in the project.

3. Communication

Table 3: Project meetings

Date	Place	Participants
April 15-16, 2014	Eindhoven	32 people from 15 partners
September 9-10, 2014	Kuopio	41 people from 16 (all) partners
February 3-4, 2015	Prague	34 people from 15 partners
May 12-13, 2015	Tampere	30 people from 16 (all) partners
September 8-9, 2015	Turku	28 people from 15 partners
January 14-15, 2016	Istanbul	28 people from 14 partners
May 10-11, 2016	Brno	29 people from 14 partners
October 4-5, 2016	Eindhoven	27 people from 14 partners
February 22-23, 2017	Delft	26 people from 15 (all) partners

Table 4: Project MT telcos and meetings

Date	Place	Participants							
		PL	WP1	WP2	WP3	WP4	WP5	WP7	Dissemination
May 6, 2014	telco	X	X		X	X	X	X	X
June 2, 2014	telco	X	X		X		X		X
July 1, 2014	telco	X	X	X	X	X	X	X	X
August 5, 2014	telco	X		X	X	X	X	X	X
September 2, 2014	telco	X				X	X	X	X
September 10, 2014	Kuopio	X	X	X	X	X	X	X	
October 7, 2014	telco	X		X		X	X	X	X
November 11, 2014	telco	X		X	X	X	X	X	X
December 2, 2014	telco	X		X		X	X	X	X
January 6, 2015	telco	X	X	X	X	X	X	X	X
February 4, 2015	Prague	X	X	X	X	X	X	X	X
March 3, 2015	telco	X	X		X	X	X	X	X
April 7, 2015	telco	X	X	X	X	X	X		X
May 13, 2015	Tampere	X		X	X	X	X	X	X
July 7, 2015	telco	X	X		X		X	X	X
September 9, 2015	Turku	X	X	X	X	X	X	X	X
October 6, 2015	telco	X	X		X	X	X	X	X
October 20, 2015	telco	X		X	X		X	X	
November 3, 2015	telco	X		X			X	X	X

Date	Place	Participants							
		PL	WP1	WP2	WP3	WP4	WP5	WP7	Dissemination
December 8, 2015	telco	X	X	X	X	X	X		X
January 15, 2016	Istanbul	X	X		X	X	X	X	X
February 2, 2016	telco	X		X		X	X		X
March 1, 2016	telco	X		X			X	X	X
March 15, 2016	telco	X		X	X		X		X
April 4, 2016	telco	X	X	X			X	X	X
May 11, 2016	Brno	X		X	X	X		X	X
June 7, 2016	telco	X				X	X	X	X
July 5, 2017	telco	X			X	X	X	X	X
September 6, 2016	telco	X		X	X		X	X	X
October 5, 2016	Eindhoven	X			X	X	X	X	X
November 1, 2016	telco	X		X	X	X	X	X	X
December 1, 2016	telco	X		X	X		X	X	X
February 3, 2017	telco	X		X	X	X	X	X	X
February 23, 2017	Delft	X			X		X	X	X
April 6, 2017	telco	X		X	X	X	X	X	X
May 2, 2017	telco	X		X	X	X	X	X	

4. Technical work

4.1 Deliverables

Table 5: Deliverables

Del. No.	Deliverable Name	Dissemination Level	Delivery Date	Actual delivery	Milestone reached
D6.1	<i>ALMARVI Project Handbook</i>	CO	M03	M03	
D6.2	<i>Project Management Plan</i>	CO	M03	M03	
D7.1	<i>Project Website and Initial Project Presentation</i>	PU	M03	M03	
D7.2	<i>Project Repository and Partners' Communication Setup</i>	CO	M03	M05	
D6.3	<i>Integration and Quality Assurance Plan</i>	CO	M06	M06	
D1.1	<i>Requirements and System Specifications</i>	CO	M08	M12	
D7.3	<i>Dissemination Plan and Strategies</i>	PU	M08	M09	MS1
D6.6	<i>Annual Progress Report-1</i>	CO	M12	M14	
D1.2	<i>ALMARVI System Architecture</i>	CO	M14	M15	MS2
D1.3	<i>Cross-Layer Models for estimating System Properties/Parameters</i>	PU	M14	M14	
D1.4	<i>ALMARVI V&V requirements and strategy</i>	CO	M14	M14	
D2.2	<i>Scalable and Low-power Video Processing Control and Transmission (Design Document)</i>	CO	M18	M19	
D2.4	<i>Parallel and Power-Aware Image Segmentation Algorithms (Architecture and Design)</i>	PU	M18	M19	
D2.5	<i>Parallel Object Recognition and Tracking, Motion Analysis Algorithms (Architecture and Design)</i>	PU	M18	M18	
D2.7	<i>Parallel Image Enhancement, Restoration, and Fusion Algorithms (Architecture and Design)</i>	PU	M18	M19	
D3.1	<i>Execution platform configuration</i>	CO	M18	M19	
D3.3	<i>Abstracting heterogeneous hardware architectures</i>	PU	M18	M19	
D5.1	<i>Medical Healthcare Demonstrator Early Prototype</i>	CO	M18	M20	
D5.3	<i>Security/Surveillance and Monitoring Demonstrator Early Prototype</i>	CO	M18	M20	MS3
D5.5	<i>Mobile Handset Demonstrator Early Prototype</i>	CO	M18	M19	
D6.4	<i>Progress Efficiency Report-1</i>	PU	M18	M19	
D7.4	<i>Exploitation Report (Intermediate)</i>	CO	M18	M20	
D7.6	<i>Dissemination Report (Intermediate)</i>	PU	M18	M18	
D2.3	<i>Video Quality Impact on ECU Algorithms</i>	CO	M24	M24	MS4
D2.6	<i>Multi-Node Camera Data Logical Analysis</i>	CO	M24	M24	
D2.8	<i>Component Implementation and Basic Integration Report</i>	CO	M24	M24	
D3.2	<i>Automatic generation of hardware accelerators and configurations</i>	CO	M24	M24	
D3.5	<i>Scalability, quality and usability of the execution platform</i>	PU	M24	M24	

Del. No.	Deliverable Name	Dissemination Level	Delivery Date	Actual delivery	Milestone reached
D4.1	<i>Application framework control</i>	CO	M24	M24	
D4.3	<i>Design Space Exploration</i>	PU	M24	M24	
D4.4	<i>Adaptive Run-Time System for Resource and Power Management</i>	CO	M24	M24	
D6.7	<i>Annual Progress Report-2</i>	CO	M24	M26	
D1.5	<i>Integration of ALMARVI System Components</i>	CO	M30	M31	
D2.9	<i>Final report on low power scalable video algorithms</i>	CO	M30	M31	
D2.10	<i>Library of low power scalable video algorithms</i>	CO	M30	M31	
D3.4	<i>Tools for adaptive cores with support of energy and performance trade-off</i>	CO	M30	M30	
D3.6	<i>Execution platform prototype</i>	CO	M30	M30	
D3.7	<i>Virtualization of heterogeneous hardware architectures</i>	CO	M30	M30	
D3.8	<i>Hardware Integration</i>	CO	M30	M30	
D4.2	<i>Tool support for static application partitioning and mapping</i>	CO	M32	M32	MS5
D4.6	<i>Integrated System Software Stack</i>	PU	M32	M32	
D5.2	<i>Medical Healthcare Demonstrator</i>	CO	M33	M33	
D5.4	<i>Security/Surveillance and Monitoring Demonstrator</i>	CO	M33	M35	
D5.6	<i>Mobile Handset Demonstrator</i>	CO	M33	M33	
D5.7	<i>Evaluation of the ALMARVI Demonstrators</i>	PU	M24	M25	
D5.7	<i>Evaluation of the ALMARVI Demonstrators</i>	PU	M36	M36	
D6.5	<i>Progress Efficiency Report-2</i>	PU	M38	M38	
D6.8	<i>Annual Progress Report-3</i>	CO	M38	M38	
D6.9	<i>Final Project Report</i>	PU	M38	M38	
D7.5	<i>Exploitation Report (Final)</i>	CO	M36	M36	
D7.7	<i>Dissemination Report (Final)</i>	PU	M36	M36	
D7.8	<i>ALMARVI Project Booklet</i>	PU	M36	M37	MS6
D7.9	<i>Standardisation Efforts</i>	PU	M36	M36	

4.2 Open meetings

Table 6: Project meetings

Venue	Date	Place	Participants
SAMOS conference/Almarvi track	July 13-23, 2015	Samos, Gr	International audience, 30 people
WEEE	September 10-12, 2015	Espoo, Fin	International audience, 50 people
ES week/ tutorial on mixed criticality	October 9-14, 2015	Amsterdam, NL	Forthcoming – expected: at least 25

4.3 Publications

- I. Pöllänen, B. Braithwaite, T. Ikonen, H. Niska, K. Haataja, P. Toivanen, and T. Tolonen, "Computer-Aided Breast Cancer Histopathological Diagnosis – Comparative Analysis of three DTOCS-based Features: SWDTOCS, SW-WDTOCS, and SW-3-4-DTOCS", *4th International Conference on Image Processing Theory, Tools, and Applications (IPTA'2014)*, Paris, France, October 14–17, 2014
- D. Goswami, D. Müller-Gritschneider, T. Basten, U. Schlichtmann, S. Chakraborty "Fault-tolerant Embedded Control Systems for Unreliable Hardware," International Symposium on Integrated Circuits (ISIC), Singapore, 2014 (December)
- T. Ikonen, H. Niska, B. Braithwaite, I. Pöllänen, K. Haataja, P. Toivanen, J. Isola, and T. Tolonen, "Computer-Assisted Image Analysis of Histopathological Breast Cancer Images Using Step-DTOCS", *14th International Conference on Hybrid Intelligent Systems (HIS 2014)*, Kuwait, December 14-16, 2014
- B. Braithwaite, H. Niska, I. Pöllänen, T. Ikonen, K. Haataja, P. Toivanen, and T. Tolonen, "Optimized Curve Design for Image Analysis Using Localized Geodesic Distance Transformations", *IS&T SPIE Electronic Imaging*, San Francisco, California, USA, February 8–12, 2015
- I.Szentandrás, M. Zachariáš, J. Tinka, M. Dubská, J. Sochor, A. Herout, "INCAST", International Symposium on Mixed and Augmented Reality ISMAR 2015, Fukuoka, Japan, October 2015
- Article in the ARTEMIS-IA news, March 17, 2015: artemis-ia.eu/news/almarvi.html
- H. Kultala, T. Viitanen, P. Jääskeläinen, J. Helkala, and J. Takala, "Compiler Optimizations for Code Density of Variable Length Instructions," in Proc. IEEE International Workshop Signal Process. System, Belfast, UK, Oct. 20-22 2014, pp. 127 – 132.
- T. Viitanen, H. Kultala, P. Jääskeläinen, and J. Takala, "Heuristics for Greedy Transport Triggered Architecture Interconnect Exploration," in Proc. International Conference Compilers Architecture Synthesis Embedded System, New Delhi, India, Oct. 12-17 2014.
- Zliobaite, I.; Hollmén, J.; Teittinen, J.; Koskinen L.; "Towards hardware-driven design of low-energy algorithms for data analysis" ACM SIGMOD Record archive, Volume 43 Issue 4, December 2014, Pages 15-20.
- Turnquist, M.J.; Hienkari, M. ; Makipaa, J. ; Koskinen, L. ; "A Fully Integrated Self-Oscillating Switched-Capacitor DC-DC Converter for Near-Threshold Loads" Accepted to The IEEE A-SSCC 2015 (Asian Solid-State Circuits Conference).
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- A.A.C. Brandon, J.J. Hoozemans, J. Van Straten, A. F Lorenzon, A. L. Sartor, A.C.S. Beck, S. Wong, A Sparse VLIW Instruction Encoding Scheme Compatible with Generic Binaries (December 2015), 2015 International Conference on ReConFigurable Computing and FPGAs (ReConFig 2015), 7-9 December 2015, Mayan Riviera, Mexico [Conference Paper]
- J.J. Hoozemans, J. Johansen, J. Van Straten, A.A.C. Brandon, S. Wong, Multiple Contexts in a Multi-ported VLIW Register File Implementation (December 2015), 2015 International Conference on ReConFigurable Computing and FPGAs (ReConFig 2015), 7-9 December 2015, Mayan Riviera, Mexico [Conference Paper]
- J.J. Hoozemans, S. Wong, Z. Al-Ars, Using VLIW Softcore Processors for Image Processing Applications (July 2015), International Conference On Embedded Computer Systems: Architectures, Modeling, And Simulation (SAMOS XV (2015)), 20-23 July 2015, Samos, Greece [Conference Paper]
- Pöllänen I., Braithwaite B., Haataja K., Ikonen T., and Toivanen P.: Current Analysis Approaches and Performance Needs for Whole Slide Image Processing in Breast Cancer Diagnostics. International Conference on Embedded Computer Systems – Architectures, Modeling, and Simulation (SAMOS XV), Samos, Greece, July 20–23, 2015.
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- Kritchalho V., Braithwaite B., Vermij E., Bertels K., and Al-Ars Z.: Balancing High-Performance Parallelization and Accuracy in Canny Edge Detector. 29th International Conference on Architecture of Computing Systems (ARCS'2016), Nuremberg, Germany, April 4–7, 2016.
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- J. Hoozemans, R. Heij, J. Van Straten, S. Wong, "VLIW-based FPGA computational fabric with streaming memory hierarchy for medical imaging applications", to appear in the proceedings of the 13th International Symposium on Applied Reconfigurable Computing, Delft, the Netherlands, 2017.
- **SAMOS XV, 2015 Special session on "Mid-Term Results of the ALMARVI ARTEMIS project"** organized by J. Takala and Z. Al-Ars includes the following publications:
 - "Multi-Constraint Multi-Processor Resource Allocation" by A. R. B. Behrouzian, D. Goswami, T. Basten, M. Geilen, H. Alizadeh Ara (**TUE**)
 - "GPU Implementation of an Anisotropic Huber-L1 Dense Optical Flow Algorithm Using OpenCL" by D. Buyukaydin and T. Akgun (**ASEL**)
 - "Using VLIW Softcore Processors for Image Processing Applications" by J. Hoozemans, S. Wong and Z. Al-Ars (**TUD**)
 - "Power Optimizations for Transport Triggered SIMD Processors" by J. Multanen, T. Viitanen, H. Linjamäki, H. Kultala, P. Jääskeläinen, J. Takala, L. Koskinen, J. Simonsson, H. Berg, K. Raiskila and T. Zetterman (**Multi-partner collaboration: TUT, UTU, NOK**)
 - "Current Analysis Approaches and Performance Needs for Whole Slide Image Processing in Breast Cancer Diagnostics" by I. Pöllänen, B. Braithwaite, K. Haataja, T. Ikonen and P. Toivanen (**UEF**)
 - "Performance evaluation of image noise reduction computing on a mobile platform" by J. Hannuksela, M. Niskanen and M. Turtinen (**VIS**)
 - "Video Chain Demonstrator on Xilinx Kintex7 FPGA with EdkDSP Floating Point Accelerators" by J. Kadlec (**UTIA**)
- **IDEA @ CPS week 2016:** ALMARVI (Twan Basten, TU Eindhoven) co-organized the 2nd IDEA workshop: Integrating Dataflow, Embedded computing and Architecture, see <http://caes.ewi.utwente.nl/idea2016>, held in conjunction with CPS week 2016, <http://www.cpsweek.org/2016>. The workshop was successful with an attendance of a bit more than 20 participants. ALMARVI researchers provided a keynote (Zaid Al-Ars, TU Delft) and an interactive presentation (Hadi Alizadeh Ara, TU Eindhoven). 2-Page abstracts of the 11 presentations were provided on the CPS week USB stick to the over 1000 participants of CPS week. Full versions of selected contributions will appear in a special section of ACM Transactions on Design Automation of Electronic Systems, <http://todaes.acm.org>.
- Embedded Systems Week Tutorial: "Design Challenges in Compute-intensive and Mixed-criticality Systems: System-, Platform- and Application-level Views", Speakers: Teun Hendriks (TNO), Zaid Al-Ars (TU Delft), Dip Goswami (TU Eindhoven).
- The tutorial jointly presented the results obtained Almarvi and EMC2 (gr. No. 621429). The tutorial was attended by an audience of 20-25 from all over the world both from industry and academia.
- Hadi Alizadeh Ara, Marc Geilen, Twan Basten, Amir Behrouzian, Martijn Hendriks and Dip Goswami, "Tight Temporal bounds for dataflow applications mapped onto shared resources", Poster and presentation in ICT-Open March 2016.
- Hadi Alizadeh Ara, Amir Behrouzian, Marc Geilen, Martijn Hendriks, Dip Goswami, Twan Basten, "Analysis and Visualization of Execution Traces of Dataflow applications", Presentation and demo in IDEA workshop April 2016.
- Hadi Alizadeh Ara, Marc Geilen, Twan Basten, Amir Behrouzian, Martijn Hendriks and Dip Goswami, "Tight Temporal bounds for dataflow applications mapped onto shared resources", Accepted for publication and presentation at the proceeding of the 11th IEEE International Symposium on Industrial Embedded Systems 23-25 May 2016.
- Amir Behrouzian, Dip Goswami, Marc Geilen, Martijn Hendriks, Hadi Alizadeh Ara, Eelco Horssen, Maurice Heemels and Twan Basten, "Sample-Drop Firmness Analysis of TDMA-Scheduled Control Applications",

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- Amir R. B. Behrouzian, Dip Goswami, Twan Basten, “Sample-Drop Firmness Analysis of TDMA-Scheduled Control Applications” **Poster and presentation in ICT Open March 2016.**
- **Participation in Intertraffic Amsterdam 2016** by CAMEA: Poster presenting pre-final results of ALMARVI project by Lukas Marsik and Lucie Brnkova. The pre-final prototype of the Zynq-based all-in-one camera with object detector has been shown as well. The audience was various industrial bodies and customers.
- Participation in TNO-ESI Symposium, Eindhoven, April 2016 by TU Delft (Joost Hoozemans and Zaid Al-Ars): Demo on real-time schedulability
- Participation in Artemis/ECSEL Brokerage 2016 Event in Strasbourg, France by UEF, by Keijo Haataja.
- Participation in HiPEAC, Stockholm, January 2017 by TU Delft (Joost Hoozemans):
 - Presentation at Workshop Reconfigurable Computing: “Improved dynamic cache sharing for communicating threads on a runtime-adaptable processor” (no formal proceedings)
 - Poster: „Liquid Architectures - The p-VEX Polymorphic VLIW Processor”
- **Participation in Digital Innovation Forum (DIF) 2017 in Amsterdam by ARTEMIS-IA and ITEA:** Presentation of Almarvi results at booth with demos from several partners: PHILIPS, UTIA, TUD
- Participation in Artemis/ECSEL Brokerage 2017 Event in Brussels, Belgium by UEF, by Keijo Haataja.
- Participation and presentation in 2nd Tensilica Day, 2017, Hanover, Germany by Pekka Jääskeläinen (TUT). Presented the TCE toolset further developed in the ALMARVI project.
- Participation and presentation in Workshop on System-Level Design for Signal and Information Processing”, Oct. 24, 2016 in College Park, MD, US by Jarmo Takala / TUT. Presented the TCE toolset further developed in the ALMARVI project.
- Participation in ICT.OPEN 2017 in Amersfoort, NL by TU Delft (Joost Hoozemans, Jeroen van Straten)
 - Presentation (full length oral presentation and poster) at PROGRESS track: ‘VLIW-based FPGA Computation Fabric with Streaming Memory Hierarchy for Medical Imaging Applications’
 - Demo of both the 64-core streaming platform and the dynamic core, awarded with the best Demo award (Meet the Demo Award 2017)

5. Conclusions

The project is finished according to plan. It addressed the following four objectives: Enabling Massive Data Rate Processing, Achieving Low Power Consumption, Composability, Flexibility, and Cross-Domain Applicability and Robustness to Variability by providing:

- Adaptive, scalable, and parallelised algorithms for image and video processing
- Cross-domain system software stack with adaptive run-time system
- Concepts for continuous hardware and software adaptations
- Cross-domain many-core execution platform
- Design tools and methods for execution platform
- Industrial-grade demonstrators for multiple application use cases