

COST

Domain Committee "Information and Communication Technologies"

COST Action (IC0805)

Start Date (*May 7 2009*)

End Date (*June 6 2013*)

*Open European Network for High Performance
Computing on Complex Environments*

FINAL EVALUATION REPORT

This Report stems from the relevant Domain Committee.
It contains four parts:

- I. Management Report*** prepared by the COST Office/Grant Holder
- II. Scientific Report*** prepared by the Chair of the Management Committee of the Action.
- III. Evaluation Report*** prepared by the "ad hoc" Evaluation Panel, established by the Domain Committee, and edited by the COST Office.
- IV. DC General Assessment*** prepared by the Domain Committee

Appendices:

none

Confidentiality: the documents will be made available to the public via the COST Action web page except for chapter *II.D. Self evaluation* and *III. Evaluation Report*.

Executive summary of the Scientific Report (max.250 words):

COST Action IC0805 "ComplexHPC" gathered many researchers from more than 26 countries. The goal of the Action was to establish a European research network focused on high performance heterogeneous computing in order to address the whole range of challenges posed by these new platforms including models, algorithms, programming tools and applications. More than 20 STSMS were carried-out between members of the Action. Two spring-schools were organized and we have edited a book with 26 chapters. From 2009 to 2013 we have worked and contributed on the following problems: scalable linear algebra using accelerators; functional languages and for parallel computations (Haskell and task parallelism); parallelization of the EULAG (Eulerian/semi-Lagrangian fluid solver) code using a hybrid model: using MPI across nodes and OpenMP within nodes ; Multilevel Model and Compiler for Task and Data Parallelism with GPUs : real time motion tracking using accelerators and heterogeneous environments; remotely sensed hyperspectral image analysis with JPEG2000 GPU-enabled compression.

I. Management Report prepared by the COST Office/Grant Holder (same layout as in the Monitoring Progress Report)



I.A. COST Action Fact Sheet

- **COST Action** IC0805: *Open European Network for High Performance Computing on Complex Environments*
- **Domain** *Information and Communication Technologies (ICT)*

- **Action details:**

CSO Approval: 24/11/2008

End date: 06/05/2013

Entry into force: 08/01/2009

Extension: (day/month/year)

- **Objectives** *The main objective of the Action is to develop an integrated approach for tackling the challenges associated with heterogeneous and hierarchical systems for High Performance Computing.*

- **Parties:** *list of countries and date of acceptance*

Austria (date)	Greece 13/03/2009	Poland 28/01/2009
Belgium 27/01/2009	Hungary 30/03/2009	Portugal 26/01/2009
Bulgaria 08/01/2009	Iceland (date)	Romania 08/01/2009
Croatia 18/04/2012	Ireland 03/02/2009	Serbia (date)
Cyprus 25/03/2011	Israel 08/09/2009	Slovakia (date)
Czech Rep. 18/04/2012	Italy 08/01/2009	Slovenia 31/07/2009
Denmark 01/04/2009	Latvia (date)	Spain 08/01/2009
Estonia (date)	Lithuania 13/05/2009	Sweden 02/02/2011
Finland 16/04/2009	Luxembourg (date)	Switzerland 31/07/2009
FYR of Macedonia (date)	Malta (date)	Turkey 02/02/2011
France 08/01/2009	Netherlands 05/10/2009	United Kingdom 08/01/2009
Germany 08/01/2009	Norway 23/01/2009	

- **Intentions to accept:**

- **Other participants:**

- *Cadence Design Systems LLC, Moscow, Russia*
- *CHPC, South Africa*

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- **Action Web site:** <http://complexhpc.org>

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WG2 Efficient use of complex systems with an emphasis of computational library and communication library

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I.C. Action Budget

COST Action IC0805 budget							
	Meetings	STSMs	Workshop	Website	School	Dissemination	Total
Year 1	50 389 €	14 200 €	0 €	2 000 €	0 €	0 €	66 589 €
Year 2	9 936 €	20 590 €	0 €	0 €	36 382 €	0 €	66 908 €
Year 3	60 565 €	27 230 €	0 €	2 000 €	0 €	0 €	89 795 €
Year 4	91 550 €	22 476 €	0 €	2 000 €	32 000 €	2 000 €	150 026 €

II. Scientific Report prepared by the Chair of the Management Committee of the Action (same layout as in the Monitoring Progress Report)

II.A. Innovative networking

- Innovative knowledge resulting from COST networking through the Action. (Specific examples of Results vs. Objectives)

In 2009-2010, the Action participants met and present their work at the first Action meeting, which took place in Lisbon at the end of October. A total of 50 talks were given during this meeting. They are available at: <http://complexhpc.org/events/lisbon/presentations.php>. Each Working Group chair also gave a presentation. This helped to foster synergies between different teams within the Action. Then, 18 applications were received for STSMs between many different groups.

In 2010-2011, the main outcome of this year Action is the spring-school that was held in Amsterdam from May 9 to May 13 2011(<http://www.cs.vu.nl/complexhpc2011/>). It gathered 46 young researchers from 11 countries and 21 different institutes during one week. The main theme of this year was High-Performance Distributed Computing, Middleware, Environments, and Tools. It featured several invited speakers among them are Rosa Badia from Barcelona, Spain and Satoshi Matsuoka from Tokyo, Japan. There have been also several *hands-on* sessions that gave the opportunity of the participants to use state-of-the-art tools and environments for performing High-Performance Distributed Computing. We believe that this was the opportunity for many young researchers to have a deep contact with the best research team in Europe and also to better know each-other.

In 2011-2012, the main outcome of this Action was the joint meeting with Action IC0804. The meeting focused on research issues on distributed computing/high performance computing and energy efficiency/power management. It gathered 16 members of our Action and around 10 members of COST Action IC0804. We discussed common issues and work plan related to both Actions. Dealing with energy efficiency is directly related to the objective of our Action.

In 2012-2013, the action had several outcomes. First, we have the book to be published by the Action by Wiley. Second we had two meetings with COST action IC0804 one in Cork in October 2012 and one in La Laguna in February 2013 each of them has featured more than 20 participants. Last, but most importantly we have the Uppsala Spring school. This school will take place from June 3 to June 7 2013 in Uppsala Sweden. It is entitled: "Heterogeneous computing - impact on algorithms" It will features 18 trainers from EU and US both from academia and private industry. There will be around 37 trainees and they will come from many different countries (Sweden, Croatia, Iceland, Belgium, Czech Republic, Greece, Lithuania, Ireland, Italy, Romania, Spain, Norway, Poland).

- Significant scientific breakthroughs as part of the COST Action. (Specific examples)

Most of the scientific results have been carried-out through Short-Term Scientific Missions (STSMs):

- Implementation and improvement of scalable linear algebra kernels working on accelerators (modern GPU connected with Infiniband).
- Parallelization of the EULAG (Eulerian/semi-Lagrangian fluid solver) code using a hybrid model: using MPI across nodes and OpenMP within nodes. This solution allows for good usage of both shared and distributed-memory system resource (memory, latency, and bandwidth). Also, the hybrid model allows for the efficient adaptation of the EULAG code to other hierarchical architectures such as clusters of multi-core processors.

- Using GPU for compression. Researchers of University of Extremadura and Poznan supercomputing center have proposed an implementation of JPEG2000 for GPUs and conclude that: “*Based on our computational experiments and benchmarks, our new GPU- based implementation of JPEG2000 proved to be a cheaper alternative in comparison to hardware solutions or less efficient CPU-based implementations.*”
- Using functional languages for parallel computation. A first collaboration between *Microsoft Research* in Cambridge and University of Uppsala, on using functional languages (Haskell) for data parallel computation was initiated. A second collaboration started between Univ. Glasgow and Bayreuth for using Haskell to support task parallelism instead of only data-parallelism
- Scheduling and partitioning data and algorithms for heterogeneous systems. The goal is to provide (near-)optimal distribution of the data for executing applications onto heterogeneous and hierarchical machines (such as the ones using GPUs and CPUs). Case studies encompass matrix multiplication (see mm.pdf annexed report) or performance models for application (see perf_mod.pdf annexed report) or scheduling algorithms.
- Multilevel Model and Compiler for Task and Data Parallelism with GPUs which targets the development of high-level programming models for CPU and GPU programming. Thus, the aim is to exploit efficiently the graphic processing units (GPUs) using CUDA architecture when processing High Definition (HD) videos in real time. The goal is to perform real time motion tracking using GPUs.
- New results for Energy efficiency especially between our Action and COST Action IC0804, through the STSM: “Evaluation and Validation of Energy Measurements in Large-Scale Distributed Systems” between Manuel Dolz and Laurent Lefevres.
- Many results in scheduling techniques especially between France (Lyon) and Greece (Thessaloniki): “Dynamic scheduling of multiple applications on elastic platforms”

Moreover, In 2012-2013, the Porto team have worked on performance modelling of the cache effect in multi-core chips. They have improved the famous *roofline model* of S. Williams, A. Waterman, D. Patterson.

- Tangible medium term socio-economic impacts achieved or expected. (Specific examples)

Many works carried out within the Action concern the use of GPUs (Graphic Processing Units), to perform scientific computation. It is expected that GPUs, and accelerators will be of major importance in the next years for high-performance scientific computing. Hence works carried out in this Action will ease the development of applications using this new hardware environment. Throughout the Action, we have strongly continued to work on GPU programming, as we understood it is a major undergoing revolution in scientific computing. This is why a full hands-on session was dedicated to this aspect during the Amsterdam spring school. An other major issue for high-performance computing we worked on, is the energy consumption as it impact the industry and the environment. This is why we have undergone joint meeting with COST Action IC0804.

An other aspect concerning socio-economic impact is the Belgium Project PSOPP started in 2012. This project is about Technology Transfer, especially for parallelizing industrial applications on GPUs. We have 4 case studies, from industries in Mechanic, Biotechnology, Numerical simulation and Buildings.

In Spain, the Murcia team collaborate with the Electromagnetic group in projects with the European Space Agency and with the company Aurorasat, dedicated to electromagnetic software. The advances in the efficient use of scientific software in heterogeneous platforms can contribute to speed-up the solution of their problems.

- Spin off of new EC RTD Framework Programme proposals/projects.

In 2011, Dana Petcu, our representative of Romania, successfully submitted a FP7-REGPOT project proposal named HOST: High Performance Computing Service Centre. It was a very competitive call as only 20 projects were selected among 300 in all fields of science. Many member of the cost Action are also member of this project such as: Krzysztof Kurowski (Poland), Antonio Plaza (Spain) or Emmanuel Jeannot (France).

- Spin off of new National Programme proposals/projects.

For 2009-2010:

1. "High performance computing on heterogeneous and hierarchical systems" grant No. 648/N-COST/2010/0 COST IC0805 funded by the Polish Ministry of Science and High Education (years 2010-2013, leader Krzysztof Kurowski)

For 2011-2012:

1. PSOPP (Porting Software On Parallel Processors), "Recherche Collective", 2012-13, Wallonia, Belgium. Partners: Cenaero and Cetic Research Centers
2. ARC-OLIMP (On Line Interactive Multimedia Processing), "Concerted Research Action", 2008-2013, FWB, Belgium.
3. Réseau de compétence TIC (Technologies de L'information ete de la communication) de la haute école spécialisée de Suisse occidentale (<http://tic.rcso.ch/>): Streaming and Analysing Genome Data (SAGeDa)
4. AAA/Switch program (<http://www.smscg.ch/>): Swiss Multi-Science Computing Grid III (SMSCG III)
5. Fondation Hasler (<http://www.haslerstiftung.ch/en/home>): Parallel Object remote Programming for Heterogeneous Wireless Networks over IPv6 (POPWIN)
6. National centre of competence, Slovenia: CCloud Assisted ServiceS –CLAS (<http://www.kc-class.eu/>)
7. HARMONIA, Poland (<http://ncn.gov.pl/finansowanie-nauki/konkursy/typy/4?language=en>): Large-Scale Computation on Heterogeneous and Hierarchical Architectures (2010-2013)
8. OPUS, Poland (<http://ncn.gov.pl/finansowanie-nauki/konkursy/typy/1?language=en>): Methods and algorithms for organization of computations in the class of anelastic numerical models for geophysical flows on modern computer architectures with realization in the EULAG model (2012-2015)

For 2012-2013, we have the following new national project:

1. "Enhancement of Server Architecture, Services and Applications", in collaboration with Polytechnic University of Valencia, University of Castilla-La Mancha, and University of Murcia (the reference of the subproject in Murcia es: TIN2012-38341-C04-03),
2. "Methods and algorithms for organization of computations in the class of anelastic numerical models for geophysical flows on modern computer architectures with realization in the EULAG model" grant No. UMO-2011/03/B/ST6/03500 funded by the Polish National Science Center (years 2012-2015, leader Roman Wyrzykowski).

II.B. Inter-disciplinary networking

- Additional knowledge obtained from working with other disciplines within the COST framework. (Specific examples)

For the whole duration of the project, the Action was not focused on interdisciplinary networking (there is no mention of interdisciplinary work in the MoU). The main reason is that we target development of computer-science tools and methodologies.

However, within working group 4 (applications), we have worked on the *catalogue of applications* for which we could test and evaluate the solutions provided within this action (see joint document COST_ApplicationsCatalogDefinition.pdf). The application catalogue is available at: <https://complexhpc-catalogue.bordeaux.inria.fr>

We have decided on a classification of applications:

- a. A1 - Research working code + publications with results
- b. A2 - Pre-application code + some documentation + publications with results
- c. A3 – Implementation + Demonstration cases

The catalogue is freely available. Any one can submit an application and browse the catalogue.

- Evaluation of whether the level of inter-disciplinarity is sufficient to potentially provide scientific impacts. (Specific examples)

Inter-disciplinarity is absent in the Action. However, all participants already have good connection with application-dependent area and we are well aware of the needs of other disciplines.

- Evaluation of whether the level of inter-disciplinarity is sufficient to potentially provide socio-economic impacts. (Specific examples)

No inter-disciplinary work within the Action.

II.C. New networking

- Additional new members joining the Action during its life.

Since the beginning of the Action, in May 2009, the following members have joined this Action: Israel (2009), The Netherlands (2009), Switzerland (2010), Cyprus (2011), Sweden (2011), Turkey (2011), Czech Republic (2012) and Croatia (2012). In November 2010, South Africa officially joined our Action as an external member.

- Total number of individual participants involved in the Action work. (Number of participants Give % of female and of Early Stage Researcher –ESR– participants).

-

In 2009, the Lisbon Working Groups meeting gathered 65 participants (10% female, 37% ESR).

In 2011, 46 persons participated to the Spring school. They were all early stage researchers around 20% were female.

In 2011-2012, we had 3 meetings, which involved around 70 persons. Around one third were ESR and 20% were female researchers

In 2012-2013, we had 5 meetings. Altogether they gathered around 140 persons. Around 1/3 were ESR and 15% are female researcher.

- Involvement of Early Stage Researchers in the Action, in particular with respect to STSMs, networking activities, and Training Schools. In addition, justification should be provided if less than 4 STSMs were carried out during the year.

In 2009-2010, we have funded 18 STSMs between January and June 2010. 16 of these STSMs (89%) involved ESR.

In 2010-2011, among the 6 STSMs that have been carried out this year, 5 were done by an ESR.

We plan to have more STSMs by the end of the grant period.

In 2011-2012, 16 STSMs have been organized this year. All of them were performed by early stage researchers. In total this represents 35 weeks of work.

In 2012-2013, we funded 12 STSMs. Almost, all of them were performed by ESR. The total amount of work sums to 36 months.

- Involvement of researchers from outside of COST Countries. (Number of participants from non-COST Countries approved by the CSO. Give % of such participants from countries with reciprocal agreements. Specify their contribution)

In 2009-2010, we had one participant from non-COST countries: Dr. Alexey Kalinov from Russia (Cadence Systems).

- Advancement and promotion of scientific knowledge through publications and other outreach activities. (Number of publications and other outreach activities that resulted from COST networking through the Action. Complete list should be given in an annex)

We have set up an *application catalogue* that gathers applications from IC0805 members. Its goal is to gather a set of HPC applications that can be used as test case or benchmark for researchers in the HPC field. The Application catalogue is available at: <https://complexhpc-catalogue.bordeaux.inria.fr>. We are also editing a book entitled "High-Performance Computing on Complex Environments" with Wiley as publisher. The structure of the book is: Numerical Analysis for Heterogeneous and Multicore Systems; Communication and Storage Considerations in High-Performance Computing; Efficient Exploitation of Heterogeneous Architectures; Efficient Exploitation of Distributed Systems; Energy Awareness in High-Performance Computing and Applications of Heterogeneous High-Performance Computing". We have gathered more than 20 chapters leading to a book with more than 400 pages. In total, 40 journal papers and 50 conference papers have been published "*thanks to the IC0805 action*".

- Activities and projects with COST network colleagues.

We had informal contacts with COST Action IC0804: Energy Efficiency in Large Scale Distributed Systems since the beginning. In 2012, we had our first meeting in Poznan. For 2012-2013, we have organized two meetings with COST Action IC0804: in October 2012 and in February 2013. The outcomes of this joint meeting are: joint chapter in our book and the book edited by IC0804; a better understanding of common problematics with, for instance, one STSM; A white paper on assumption about energy efficiency in HPC; and a new COST proposal on sustainable computing.

- The capacity of the Action members to raise research funds.

In 2011, we have been successful in highly competitive call (FP7-REGPOT).

IV. DC General Assessment prepared by the Domain Committee

All signs indicate that this COST Action is a great success. It involved 26 European countries and 2 external ones (Russia and South-Africa). Two spring schools, three workshops, and 12 meetings were held. 52 STSMS have been carried out. A new FP7-REGPOT project coming from this Action has been funded. It has been prepared and successfully submitted by COST Action members in the context of a very competitive call where only 20 projects were selected among 300 in all fields of science. This project, named HOST: High Performance Computing Service Centre, gathers many other member of the COST Action. A new COST Action is proposed been together with Action IC0804.

An application catalogue available at: <https://complexhpc-catalogue.bordeaux.inria.fr> has been set up. A book with more than 400 pages and entitled "High-Performance Computing on Complex Environments" has been being edited. In total, 40 journal papers and 50 conference papers have been published in the framework of the IC0805 Action. The scientific results can be grouped in the following domains:

- GPU-based applications for compression, High Definition (HD) real time motion tracking, and scalable linear algebra kernels.
- (Near-)optimal distribution of the data for executing applications onto heterogeneous and hierarchical machines (such as the ones using GPUs and CPUs).
- Use of hybrid model (MPI and OpenMP) in case of hierarchical architectures such as clusters of multi-core processors (parallelization of the EULAG).
- Using functional languages (Haskel) for parallel computation (data- parallelism as well task-parallelism).
- New results for Energy efficiency especially between Action IC0804 and Action IC0805, through the STSM: "Evaluation and Validation of Energy Measurements in Large-Scale Distributed Systems".

It is clear that one of the greatest successes of the Action is the strengthening of the European research network in the domain. Many STSMs have been done through new network connections. Spring schools are seen as a major success and extremely useful for the young researchers. Many PhD theses have been defended and some of the MC members have been in the defence boards.