



FP7 – 216693 - MULTICUBE Project

MULTI-OBJECTIVE DESIGN SPACE EXPLORATION OF MULTI-PROCESSOR SOC ARCHITECTURES FOR EMBEDDED MULTIMEDIA APPLICATIONS

Deliverable D3.1.2: Final Prototype of the Open-Source MULTICUBE Exploration Framework

Revision [2]

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	
Nature of Deliverable		
R	Report	
P	Prototype	X
D	Demonstrator	
O	Other	



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Abstract: This deliverable (issued at M24) presents the results of the activity carried on from M4 to M24 in Task 3.1 (Definition of the Open Source Framework for Design Space Exploration) under the leadership of POLIMI, with contributions from POLIMI, ALARI and reviewed by UC and ESTECO.

The main goal of this deliverable is the release of the Final Prototype of the Open-Source Exploration Framework, named *Multicube Explorer*. This deliverable updates and extends deliverable D3.1.1 (Initial Prototype of the Open-Source Exploration Framework) by introducing:

- Response Surface Modeling techniques, as described in deliverable D2.3.2 (Refined and Extended Multi-Objective Evaluation Metrics).
- Enhanced *design-of-experiments* and extension of *optimization algorithms* to manage *masks* and *permutation* types.
- Introduced HTML reporting capabilities.
- Compliancy with release R1.4 of the MULTICUBE XML interface.
- Bug fixes to improve the overall stability and memory consumption of the tool.

The current version of the tool is *final* since it contains all the required optimization algorithms, design of experiments modules and response surface modules. Besides, the tool has been extensively debugged and offers a robust and mature engine for MPSoC design space exploration.

This report contains:

- A summary of the structure and functionality of the *final* version of the Multicube Explorer tool.
- The current internet address of the web page from which the Multicube Explorer can be downloaded.
- A snapshot of the current Multicube Explorer web site content.

Approved by the Project Coordinator:



Date: February 1st, 2010



Table of contents

I. Executive summary.....	4
II. Link to the website of the prototype.....	6
III. Content of the website of the prototype	7
III.1. Home page.....	7
III.2. Overview page.....	8
III.3. Example page.....	11
III.4. Source code download page	12
III.5. License page	13
III.6. Documentation page	14
III.7. Team page.....	14
IV. Summary	15



I. Executive summary

This deliverable consists in the *Final Prototype of the Open-Source Exploration Framework*, named Multicube Explorer. Multicube Explorer is a design space exploration tool for supporting platform-based design. It allows a fast optimization of parameterized system architecture towards a set of objective functions (e.g., energy, delay and area), by interacting with the Use Case simulator of the target architecture by means of the MULTICUBE XML interface defined in D1.4.1 (Definition of the Specification of the Design Flow Integration). This deliverable updates and extends deliverable D3.1.1 (Initial Prototype of the Open-Source Exploration Framework) by introducing:

- **Response Surface Modeling techniques**, as described in deliverable D2.3.2 (Refined and Extended Multi-Objective Evaluation Metrics). In particular, the following Response surface models have been implemented:
 - *Linear regression*
 - *Shepard Interpolation*
 - *Splines*
 - *Radial Basis Functions*
 - *Neural Networks*
- **Enhanced design-of-experiments and extension of optimization algorithms** to manage masks and permutation types.
 - Enhanced DoEs: *random, two-level full factorial, two-level full factorial extended, scrambled.*
 - Enhanced optimizers: *APRS, MOSA, MOPSO, NSGA-II, FEMO, GEMO, SEMO.*
- Introduced **HTML** reporting capabilities:
 - Bi-dimensional scatter plots for objective functions including Pareto fronts.
 - Box-Plot statistic analysis tools
 - Main effect analysis
 - Interaction analysis
 - Surface plots
- Compliancy with release **R1.4** of the **MULTICUBE XML** interface.
- Bug fixes to improve the overall stability and memory consumption of the tool.

The current version of the tool is final since it contains all the required optimization algorithms, design of experiments modules and response surface modules. Besides, the tool has been extensively debugged and offers a robust and mature engine for MPSoC design space exploration.

The tool is composed by an exploration kernel that orchestrates the functional behavior of the design of experiments, optimization algorithms and response surface models. The kernel module is responsible for reading in the design space definition file (in the MULTICUBE XML R1.4 format) and accepting commands from the shell interface (or the corresponding script). It then exposes the parameters of the design space to all the modules involved in the optimization process (design of experiments and optimization algorithms) by means of a suitable core design space representation. The tool provides commands for creating response surface models (i.e., analytical approximations of the system metrics of unknown configurations) to speed-up the optimization phase.



This report is structured as follows. Section 2 presents the link to the website from which the Multicube Explorer tool can be downloaded. Section 3 presents a summary of content of the website where the source code, license and documentation can be found.



II. Link to the website of the prototype

The public website of the Initial Prototype of the Open-Source MULTICUBE Exploration Framework can be reached by following the appropriate link on the MULTICUBE official website under the open-source tools page:

http://www.multicube.eu/open_source.html

Alternatively, the website can be reached directly with the following link:

<http://m3explorer.sourceforge.net/>


The following is a snapshot of the home page:

Home Overview Example Source License Documentation Team

Multicube Explorer

Multicube Explorer is a design space exploration tool for supporting **platform-based design**. It allows a **fast optimization** of parameterized system architecture towards a set of objective functions (e.g., **energy, delay and area**), by interacting with a **system-level simulator**. Multicube Explorer provides a set of innovative sampling and **optimization techniques** to help finding the best objective-function trade-offs. It also provides a set of **Response Modeling Methods** for increasing the speed of the optimization phase and an open **XML** interface for supporting new platforms/architectures.

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 Team Leader: Vittorio Zaccaria [[home](#)]
 Development Team: Gianluca Palermo, Giovanni Mariani, Fabrizio Castro

Release 1.0, December 23rd - 2009. Major new features:

- Added **response surface models (RSM)** among which **splines** and **neural networks**
- **Extended design of experiments** techniques for managing masks and permutations
- Improved **stability** and **memory usage**






Figure 1: Screenshot of the home page of the public website of Multicube Explorer.

III. Content of the website of the prototype

The website is composed of the following webpages:

- Home page
- Overview page
- Example
- Source page
- License page
- Documentation page
- Team page

The following sections describe in detail the content of each page with a small summary highlighted in *italic*.

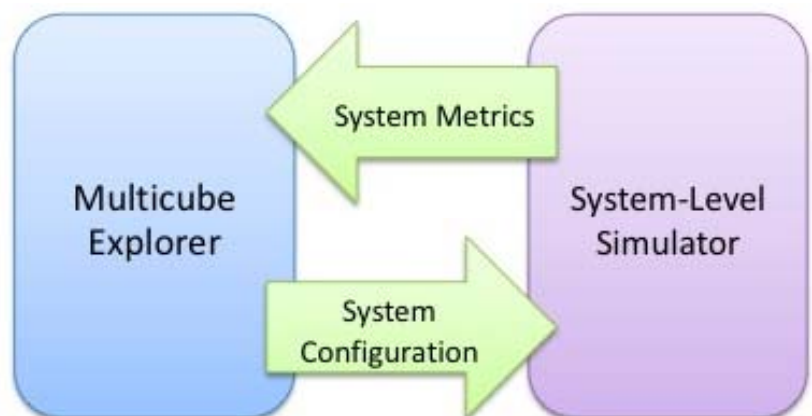
III.1. Home page

This page is the welcome page for the Multicube Explorer Open Source Exploration Tool. It gives a brief overview of the tool goals and features and provides information on the people involved in the development.

Multicube Explorer

Multicube Explorer is a design space exploration tool for supporting platform-based design. It allows a fast optimization of parameterized system architecture towards a set of objective functions (e.g., energy, delay and area), by interacting with a system-level simulator. Multicube Explorer provides a set of innovative sampling and optimization techniques to help finding the best objective-function trade-offs. It also

provides a set of Response Modeling Methods for increasing the speed of the optimization phase and an open XML interface for supporting new platforms/architectures.



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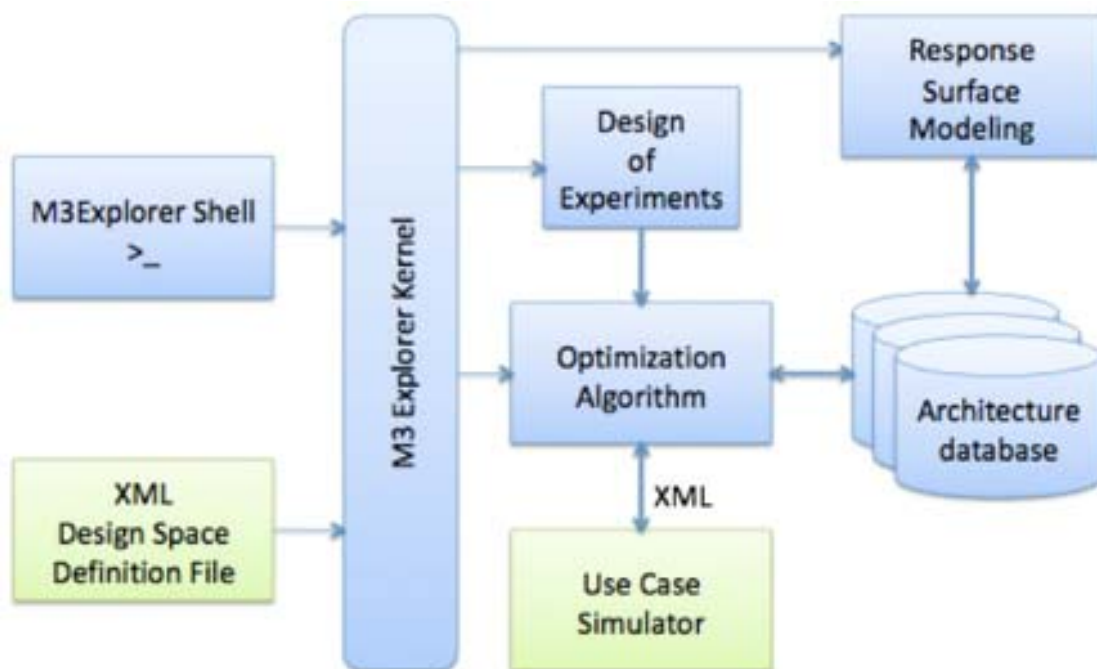


III.2. Overview page

This page gives an overview of the tool structure and composition by highlighting the functionality and features offered to the user. It also highlights the interfaces with the use case simulators.

Overview of Multicube Explorer

Multicube explorer is an interactive program that lets the designer explore a design space of configurations for a parameterized architecture for which an executable model (use case simulator) exists. Multicube explorer is an advanced multi-objective optimization framework which is entirely command-line/script driven and can be retargeted to any configurable platform by writing a suitable XML design space definition file and providing a configurable simulator.



Goals of Multicube Explorer

The overall goal of the open source design space exploration framework aims at providing a retargetable tool to drive the designer towards near-optimal solutions to the architectural exploration problem, with the given multiple constraints.

The final product of the framework is a Pareto curve of configurations within the design evaluation space of the given architecture.

Automatic design space exploration

One of the goals of the open source tool is to provide a command line interface to the exploration kernel that allows the construction of automated exploration strategies. Those strategies are implemented by means of command scripts interpreted by the tool without the need of manual intervention. This structure can easily support the batch execution of complex strategies that are less prone to human intervention, due to their execution time.

Portability

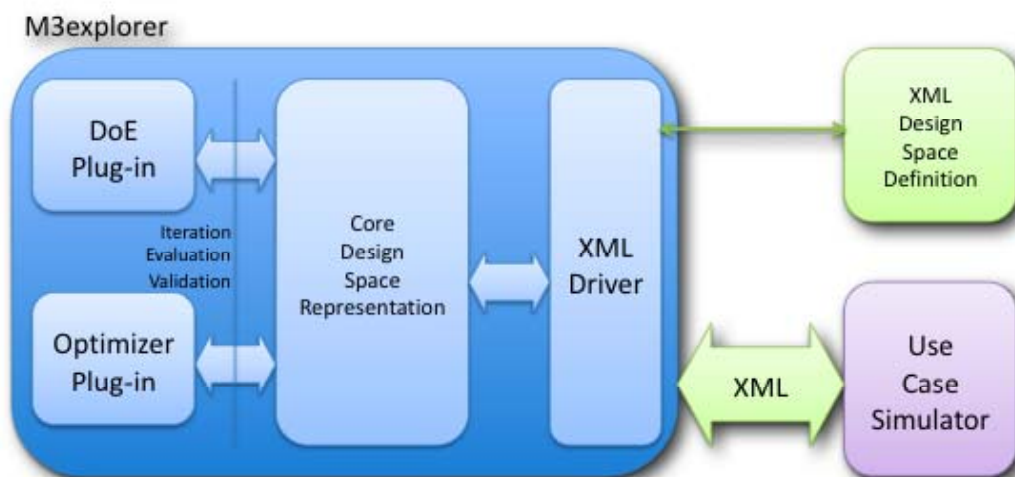
Another goal of the open source tool is to be portable across a wide range of systems. This goal will be achieved by not sacrificing the efficiency of the overall exploration engine. The standard ANSI C++ programming language will be used for developing the open source framework. The Standard Template Library as well as other open source libraries will be used during the development process.

Modular composition

One of the strength of the open-source tool is the modularity of its components. Simulator, optimization algorithms and other design space exploration components are dynamically linked at run-time, without the need of recompiling the entire code base. This will be supported by well-defined interfaces between the drivers supporting the simulation and the optimization algorithm. This will strongly enable the introduction of new modules for both academic and industrial purposes. Given the modular decomposition, a single optimization algorithm can be used for every use case simulator. Moreover, a single use case architecture can be optimized with a wide range of optimization algorithms.

Architecture of the tool

The tool is basically composed by an exploration kernel which orchestrates the functional behavior of the design of experiments and optimization algorithms.



The kernel module is responsible for reading in the design space definition file (in XML format) and accepting commands from the shell interface (or the corresponding script). It then exposes the parameters of the design space to all the modules involved in the optimization process (DoE, Optimization Algorithms) by means of a core design space representation.

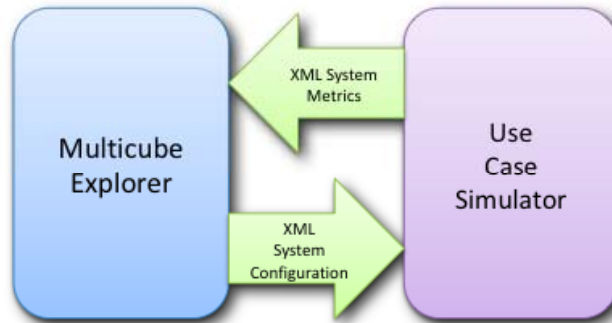
The core design space representation provides a set of abstract operations that are mapped on the specific use case under analysis. The abstract operations are represented by iterators over the feasible design space, among which we can find:

- Full search iterators.
- Random search iterators, (global and neighborhood).
- Factorial iterators (two-level, two-level + center point).

The core design space representation provides also services for validating architectural choices at the optimizer level and evaluating the associated objective functions. The objective functions are defined as a subset of the use case system level metrics and can be manipulated by the user by interacting with M3explorer.

Interaction with the simulator

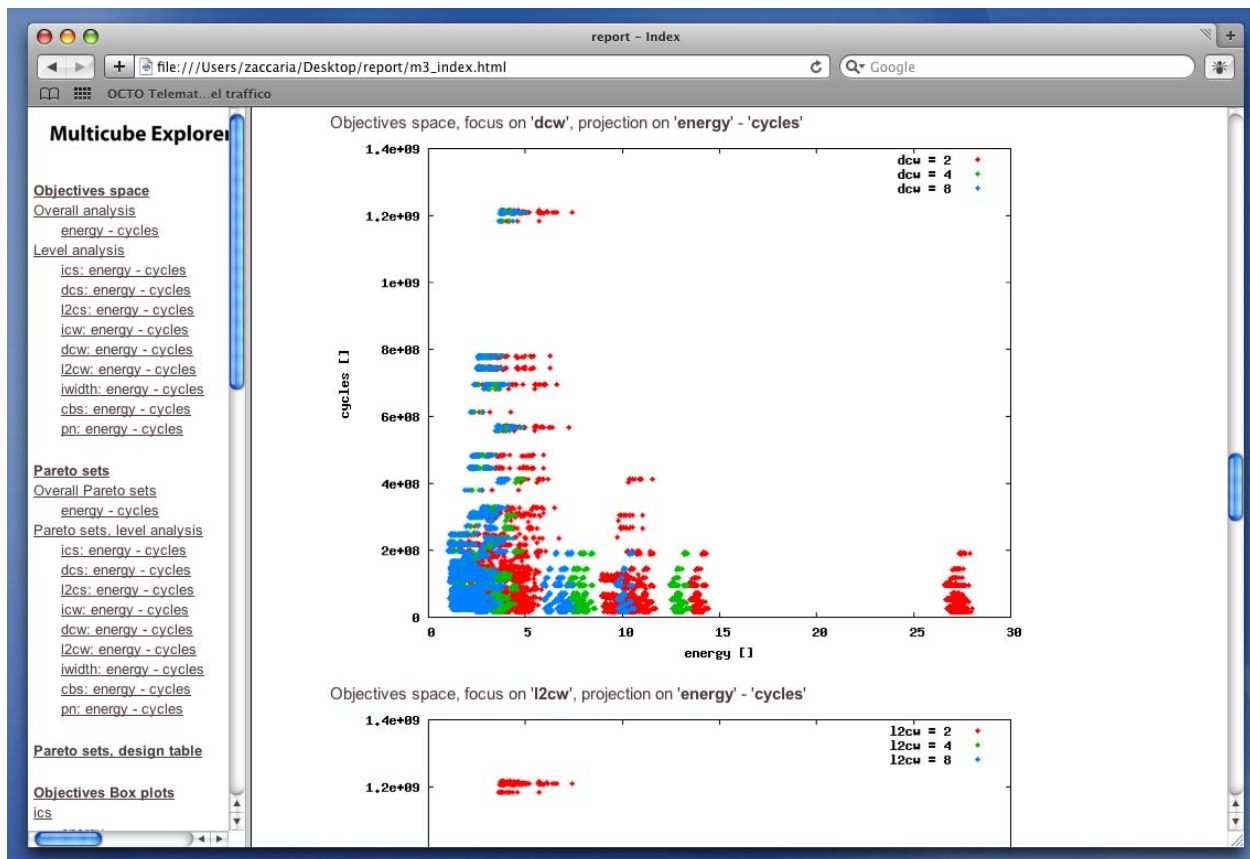
The design space exploration is performed by using the simulation abstraction layer exported by the XML driver to the optimizer plug-ins. In principle, the optimizer instantiates a set of architectural configurations by means of the design space iterators, and passes the corresponding representation to the XML driver which will execute the simulator. Information about simulator runs will be displayed directly on the M3explorer shell.



M3Explorer creates a specific directory to execute each instance of the simulator. In this directory, a valid system parameters file is created before starting the simulator. A system metrics file is expected to be obtained as the output of the simulator execution.

III.3. Example page

This page gives an overview of an example HTML report generated by Multicube Explorer. The target architecture is a shared-memory multiprocessor with private L2 cache running and MPEG2 decoder. We focused our analysis on a set of architectural parameters among which the memory subsystem parameters, the number of processors and the issue width. Globally, the resulting design space consists of 2^{17} alternative configurations. To carry out the system metrics evaluation, we leveraged the SESC simulation tool, a fast simulator for chip-multiprocessor architectures with out-of-order processors that is able to provide energy and performance results for a given application. Within SESC, the energy consumption computation for the memory hierarchy is supported by CACTI, while the energy consumption computation due to the core logic is based on the WATTCH models. The exploration flow is composed by a randomized design of experiments over the entire design space of the use case. We selected a subset of the system metrics to be used as objective functions for the analysis. For this preliminary design space exploration, we selected the following, relevant system metrics the cycles of execution of the target application and the power dissipation.



III.4. Source code download page

This page provides the link to download the initial prototype of the Multicube Explorer open-source exploration framework. It also provides information about the pre-requisite programs to be installed before compiling and running Multicube Explorer.

Latest stable release:

December 23rd, 2009- Release 1.0 - [[multicube_release_1_0.tar.gz](#)]

For any bug report, please write to Vittorio Zaccaria: zaccaria@elet.polimi.it

Prerequisite programs and libraries:

1. GCC g++ 4.0.1 or higher
2. Libxml2
3. Bison/YACC parser generator
4. Flex/Lex lexical analyzer

Supported platforms:



III.5. License page

This page shows the open-source licensing terms associated with Multicube Explorer.

Multicube explorer is open-source and it is released under the BSD license:

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III.6. Documentation page

This page links to the current documentation of the open-source exploration tool. It is composed by a user manual (in pdf format) and an on-line HTML developer documentation that has been created with doxygen.

User Manual

Multicube Explorer, User Manual version 1.0:

http://home.dei.polimi.it/zaccaria/data/release_1_0/docs/pdf/user_guide.pdf

API documentation for developers

Multicube Explorer, API Documentation version 1.0:

http://home.dei.polimi.it/zaccaria/data/release_1_0/docs/html/annotated.html

III.7. Team page

This page shows some information about the development team.



IV. Summary

In this report we presented the main features of the Multicube Explorer tool version 1.0 and the website content from which it can be downloaded. This is a descriptive document that accompanies the main deliverable D3.1.2 prototype tool whose source code downloadable at:

<http://m3explorer.sourceforge.net/>

