MOBY-DIC

Grant Agreement Number 248858

Model-based synthesis of digital electronic circuits for embedded control

Publishable summary

Report version:	1
Due date:	M24 (second periodic report)
Period covered:	December 1, 2010 – November 30, 2011
Report preparation date:	January 23, 2012
Classification:	Public
Involved people:	Marco Storace wrote this report
	Each partner revised and contributed to this report
Related to Workpackage:	1 – Project Management

Project funded by the European Community under the FP7 "Information & Communication Technologies" Programme.

Contract start date:	December 1, 2009 **Duration**: 36 Months
Funding scheme:	Small or medium scale focused research project (STREP)
Project Coordinator:	Prof. Marco Storace, Università degli Studi di Genova (UNIGE)
Partners:	Technische Universiteit Eindhoven (TUE), Universidad de Sevilla (USE-IMSE), Università degli Studi di Trento (UNITN), Ford Forschungszentrum Aachen GmbH (FFA), ON Semiconductor Belgium BVBA (ON-SEMI), IMT Alti Studi Lucca (IMTL)
Project website address:	http://www.mobydic-project.eu/

Summary description of project context and objectives

KEYWORDS: Embedded control systems, circuit design, piecewise affine functions, optimal control, virtual sensors.

In spite of the importance of embedded control in daily life, there is a surprising lack of methods to design and deploy embedded control systems in a systematic and highly efficient manner. There is an abundance of methods for the separate design of the control algorithms eventually embedded into a hardware platform, or to create a suitable hardware platform for the implementation of a given control algorithm. However, an automated and integrated design flow from mathematical models of the embedding physical system to electronic circuits is at present not available.

The MOBY-DIC project will research and develop a unique paradigm and supporting tool chain for the design of embedded control systems, based on modelling of the physical process and integrated design of both control algorithms and embedded circuits.

MOBY-DIC has identified the following project objectives to face the posed research challenges:

O.1 Define a novel PWA (PieceWise-Affine) canonical formalism that unifies the control and circuit views on embedded control design, and develop analysis, complexity reduction and controller and circuit design methodologies for the embedded electronics, starting from mathematical models of the embedding system.

O.2 Create a complete integrated tool chain of software modules to support the new analysis and design methodologies.

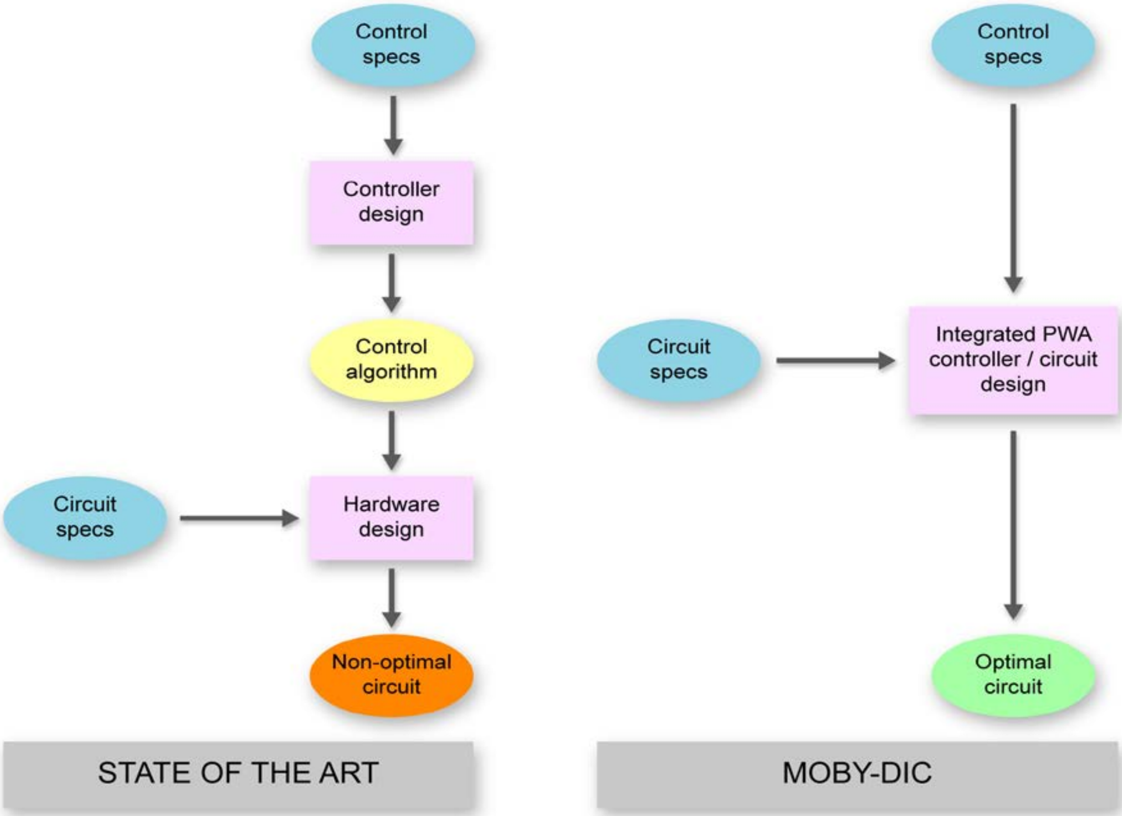
O.3 Provide a proof-of-concept of the new approach by addressing four challenging industrial case studies in the automotive domain, which require the design of embedded controllers and virtual sensors:

- CS1) monitoring batteries for micro-hybrid vehicles
- CS2) design of a virtual smart full gyro sensor for vehicle dynamics applications
- CS3) Stop-&-Go Adaptive Cruise Control, a functionality already available in some upper-class vehicles, which automatically adapts the vehicle's speed depending on a predecessor's behaviour, steering the throttle as well as the brake system
- CS4) control of a pulse width modulation (PWM) DC-DC buck converter.

The developed methodologies and tools are generic in nature with the consequence that they are usable in any application domain such as industrial and electronic automation, robotics, transportation, aerospace, health care, etc.

On the theoretical level, MOBY-DIC aims at developing analysis and synthesis methods for PWA controllers and estimators that can trade-off performance properties of the overall system and the implementation complexity of the resulting digital circuits. MOBY-DIC proposes a circuit-oriented design flow based on the PWA paradigm that, starting from a model description, ends with an (even integrated) embedded system. The availability of such a design flow will actually spur the application of PWA controllers and virtual sensors for many applications and will alleviate the obstructions in their usage as caused by the decoupled designs of the (mathematical) control law and of the circuit.

In other words, MOBY-DIC will provide circuit-aware embedded control design and control-aware embedded circuit design, by employing a PWA modelling paradigm, which provides a flexible formalism, efficient control design tools, and efficient implementation in electronic circuits.



Partners:

Università degli Studi di Genova – UNIGE (Italy)

Technische Universiteit Eindhoven – TU/e (Netherlands)

Universidad de Sevilla – USE-IMSE (Spain)

Università degli Studi di Trento – UNITN (Italy) (ended 30 November 2011)

IMT (Institutions, Market, Technologies) Alti Studi Lucca – IMTL (Italy) (started 1 July 2011)

Ford Forschungszentrum Aachen GmbH – FFA (Germany)

ON Semiconductor Belgium BVBA – ON-SEMI (Belgium)

1.1 Description of the work performed since the beginning of the project and the results achieved so far

According to the Description of Work, the first year of the project has been mainly devoted to set the bases for some of the main project activities, concerning:

a) The generalization of the circuit implementation technique developed by UNIGE to PWA functions which may be discontinuous, governed by hysteretic relationships and/or defined over non-uniformly partitioned domains.
b) Stability analysis, derivation of mathematical expressions for the approximation errors, complexity reduction issues.
c) The choice of architectures from the state of the art (plus possible alternatives).
d) The definition of basic circuit structures to be used in the electronic implementations of PWA control systems.
e) The mathematical definition of the four case studies (CS1 to CS4).
f) The definition of a general protocol for the electronic circuit design and implementation of circuit-oriented PWA control systems, providing a complete path from mathematical modelling of control/estimation problems to the design of circuit architectures able to solve the same problems.
g) Organization and start of the dissemination activities; several papers already published.

The second year has been mainly devoted to:
a) Refine/optimize the protocol for the electronic circuit design and implementation of circuit-oriented PWA control systems, also on the basis of feedbacks from the case studies.
b) Implement a software toolbox realizing the aforesaid protocol, from the mathematical model description (in a user-friendly specification language) to its synthesis in MATLAB environment for numerical simulation and in VHDL for hardware implementation.
c) Apply the software toolbox to the case studies.
d) Design and implement on FPGAs circuits realizing PWA functions (in particular, for the case studies).
e) Define experimental tests to validate the implemented FPGA circuits.
f) Analyse costs, benefits and performances of VLSI solutions, to realize the case studies with very high performances (e.g. low power, high speed or minimum size). Selection of a chip architecture, design and simulation of a chip incorporating such architecture.

The fourth case study (CS4), concerning the control of a pulse width modulation (PWM) DC-DC buck converter in automotive applications, was initially not part of the project, but during the virtual meeting held on April 27 2010, the Management Committee decided to add it. During this second year it became apparent that the virtual sensor approach envisioned for Case Study 1 cannot be applied in this case. It was therefore decided to drop this case study and refocus the resources on Case Study 4.

A detailed description of the work performed is reported in section 2.2 of this document.
A video giving a good understanding of the goals of the project, without being too technical, is available at the following web address:
http://ncas.dibe.unige.it/mobydic/MOVIE.wmv

1.2 Expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far)

MOBY-DIC is expected to impact all major goals of the work programme, in particular:
- Significantly increased productivity of embedded system development.
- Improved competitiveness of European companies that rely on the design and integration of embedded systems in their products by reducing design costs and time to market.
- Emergence and growth of new companies that supply design tools and associated software.
- Reinforced European scientific and technological leadership in the design of complex embedded systems.

Scientific impact - Reducing the gap between control and circuit worlds will provide a quite different design perspective, offering important advantages in terms of design efficiency, higher performance, control improvement.

Economical impact - The advantages brought by the scientific domain will be exploited by the industrial partners: one supplier of efficient power solutions to customers in the power supply, automotive, communication, computer, consumer, medical, industrial, mobile phone, and aerospace markets and one major player of the automotive industry, who uses embedded control in its products. The presence of major European industrial players in the consortium will enable rapid commercialisation of the project outputs, wide spreading the concept throughout European industry, enhancing European competitiveness in the embedded control system market and ultimately leading to new high technology jobs for European workers.
Societal impact - The society would experiment benefits through the reduction of costs in, initially, automotive products, but extensible to other many manufactured products, also owing to the advices of the MOBY-DIC panel of external industrial advisors. Embedded control systems end-users can expect a reduction for their costs.

A detailed description is reported in deliverable D6.3 and in section 2.2 of this document.

1.3 Address of the project public website

www.mobydic-project.eu

