Impact of platform-based design methodology in Magneti Marelli Powertrain design flow

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The investigation on advanced design methodologies for the design flow of automotive control systems has been the main subject of collaboration between Magneti Marelli Powertrain and PARADES, since PARADES' foundation in 1996.

The contributions from PARADES on this subject resulted in extensions of the classical platform-based design methodology, originally proposed for HW/SW design of electronic devices, to cover the entire design flow of automotive embedded control systems that ranges from customer specification, to control algorithms design and HW/SW as well as mechanical implementation. The proposed extensions included the definition of representations of the system under design at high levels of abstraction, on the top of the HW/SW partitioning abstraction layer. On the top layers, the desired behavior of the controlled system is analyzed and the functional behavior of the embedded control system is specified.

The introduction of the extended platform-based design methodology obtained from this research activity inside Magneti Marelli Powertrain, allowed the company to improve significantly the design flow and suit it to the challenging needs of today automotive market. The adoption of the new design methodology involved major efforts in terms of reorganization and training inside the company, which lasted for a few years.

To be able to meet the extremely tight constraints on cost and development time imposed by the market for the production of automotive control systems, implementing the increasingly complex functionalities required by car manufactures,

- component re-use at all levels of abstraction and
- early evaluation of platform requirements, which prevents costly and time consuming re-design cycles,

had been key issues to be addressed.

The principles of platform-based design had been evaluated by Magneti Marelli Powertrain to be successful to cope with these issues. In platform-based design, the design process is described as a set of successive refinement steps from a level of abstraction as high as possible all the way down to the details needed for the final implementation. The following layers of abstraction and design steps had been identified:

- System layer: formalization, breakdown and analysis of system specifications;
- Function layer: decomposition of the system in functions and function deployment;

- Operation layer: definition of the functional behavior in terms of atomic elements referred to as operations (e.g. measurement, control, actuation, transformation, etc.);
- Architecture layer: definition of HW and SW architectures and mechanical components specification;
- Component layer: design of components not available from previous design flows.

In the last years, an internal Magneti Marelli Powertrain project, devoted to the reorganization of the design flow for the development of engine control units (ECUs) for motorcycles, motivated the investigation on the integrated control-implementation design methodology, partially supported by the E.C. project COLUMBUS. In next future, tighter laws on emission will force the adoption of more complex embedded controllers for motorcycles, which will be still considerably less complex than the ones designed for cars but at the same time, exhibit all the tight interactions with the plant typical of car applications that make the design of ECUs very challenging. To be able to meet cost and development time targets, re-usability of design solutions at all levels of abstraction is essential for this type of products.

In the integrated control-implementation design methodology, the design step from the operation abstraction layer to the architecture abstraction layer has been refined to better quantify the interactions in the design flow between the design of control algorithms and their implementation. The underling motivation is the prevention of long re-design cycles in the design flow, when the timing and accuracy requirements of the applications are not met. Based on the desired closed-loop performances, the requirements on the implementation architecture for each control algorithm are evaluated and the effects of the actual implementation are represented by abstract models characterized by idealized parameters. Each choice of these parameters identifies an implementation platform. In this view, the implementation of control algorithms is a platform mapping with as many implementation details as exposed by the implementation platform.

In particular, the work was focused on the following three layers of abstraction: the function layer, the operation layer and the implementation abstraction layer. The importance of these platform layers derives from the fact that most of the critical design choices are taken in the early stages of the design flow and missteps in these stages produce costly and time consuming re-design cycles. These layers support designs built upon them allowing the designer to be freed from lower-level details, but letting enough information transpire about lower levels of abstraction to allow design space exploration with a fairly accurate prediction of the properties of the final implementation.

The proposed integrated control-implementation design methodology allowed us to:

- evaluate in terms of performance degradation the *main* effects of control algorithm implementation at the very early stage of design, when the control solution is conceived;
- formally express the constraints on the implementation platform that guarantee fulfillment of the system specification.

The application of the proposed design methodology to a motorcycle engine control system, which included formalization of system specifications, functional decomposition and deployment, controllers selection and modeling of abstractions of potential implementations, had been carried out by teams of 4-6 Magneti Marelli Powertrain control engineers and PARADES' and the University of L'Aquila's researchers, in a sequence of nine full–day meetings held in Magneti Marelli Powertrain from mid May to the end of June, 2003.

In conclusion, Magneti Marelli Powertrain evaluates definitely interesting the approach of the integrated control-implementation design methodology, developed with the support by the E.C. project COLUMBUS, and will proceed with the collaboration with PARADES and University of L'Aquila to complete the introduction of the methodology in the company.