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Concept of Software Factory for Embedded Systems in Automotive Industry

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ABSTRACT

One of the main problems encountered in the design of embedded systems is how to handle the reuse of software, because it plays an important leading role in the automotive business.

The target is to use the Software Factory (**SF**) concept considering the hardware also. For this reason, it is suggested to rename the concept to Embedded Factory (**EF**) congregating the orderly and efficient reuse of hardware and software components.

With the intention of address the EF to the automotive industry productiveness, four processes must be considered:

- A precise definition about the **Family of Products**, considering the range of the portfolio;
- A robust implementation of the **Product Line** concept, for the purpose of enable the industrialization of the embedded systems development.
- The use of the **Economy Concept** seeing reuse, scope, scale and supply chain;
- The execution of **Best Practices** for software and hardware development;

Once applied the items above and therefore the EF concept, it is possible to reach 10 effective advantages:

1. Gain in Time-to-Market;
2. Parallel Development;
3. Processes Standardization;
4. Faster Return of Investment (ROI);
5. Efficiency in Costs and Time determination;
6. Reuse of developed parts from previous products;
7. Better specification of components;
8. Quality Improvement;
9. Assertiveness in the process of Verification and Validation (V&V);
10. Knowledge Preservation.

INTRODUCTION

Nowadays, the complexity of embedded systems in vehicles, considering software and hardware components, has increased exponentially and at the same level, the competitiveness of the globalized automotive market.

In this scenario, one of the greatest rules for perpetuation of the business is to give a greater added value and attractive costs than competitors.

Considering this, it is necessary to break the old paradigm that “each product is completely different from the others” and to rebuild it considering being faster than competitors in time-to-market of new products with competitiveness in all instances as cost, added value, shape and compatibility with other systems with the reuse of engineering effort from previous developments of the same family of products.

The Software Factory (SF) is an ordered structure with the purpose of prevents the completion of a development without the benefit of the knowledge acquired and produced in the previous development of similar applications. Reinforces and directs consolidated practices for developments with benefits in increased productivity, quality and capacity of develop flexible applications.

The purpose of this paper is to adjust the Software Factory (SF) concept for Embedded Systems Development applying it in the automotive reality. For this purpose, here the Software Factory is renamed to Embedded Factory (EF), presenting an organized structure to work with the competitive market scenario from an administrative point of view seeing the Development Process as a whole.

EMBEDDED FACTORY IN THE SYSTEMS ENGINEERING ENVIRONMENT

Before entering deeply into the concept recommended in this paper it is necessary to make uniform the understanding about what is a system and what is system engineering.

SYSTEM DEFINITION

System is a cluster of different components that together produces results not reachable by the components on your own.

The components can contain persons, hardware, software, facilities, policies, documents and all other things necessary to create systems-level results. [2]

The results include system level qualities, properties, characteristics, functions, behavior and performance.

The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected. [1]

SYSTEMS ENGINEERING DEFINITION

Systems engineering is a discipline whose responsibility is creating and executing an interdisciplinary process to guarantee that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle. [1]

ABSTRACTION LAYERS OF SYSTEMS ENGINEERING

Now that the definitions were given, the next step is to define the layer in the Systems Engineering that the EF can be useful.

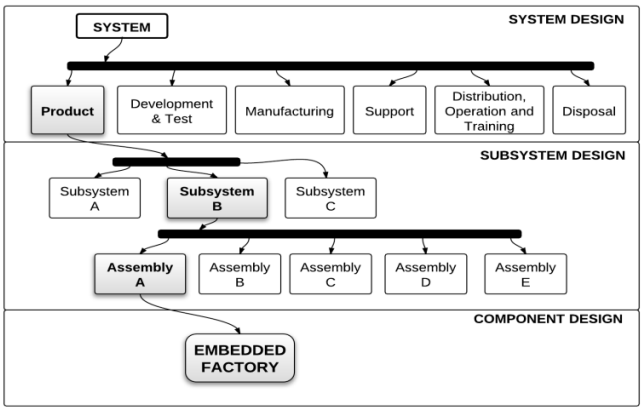

Figure 1 - System Breakdown Structure

Considering the vehicle as the system and the engine, ECU, electrical center, brake, etc. as subsystems, the EF is intended to be applied at Component Level, as shown in the Figure 1.

Once the Component Design Layer is reached, the multidisciplinary engineering is not effective anymore. Then, it is necessary to guide the development with specific methods belonging to each technology.

Following this premise, the EF concept is suggested from the Component Layer to the end of the development.

REUSE OF ENGINEERING EFFORT IN THE EMBEDDED SYSTEMS

In order to apply the EF concept and reach the success in the reuse, it is necessary to understand the four main tools that compose the EF.

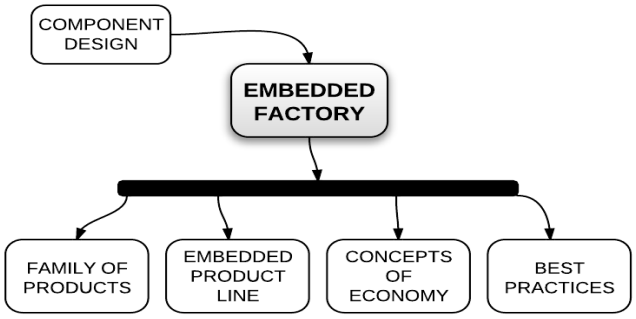

Figure 2 - Conceptual Model Proposed for EF

The tools are Family of Products, Embedded Product, Concept of Economy and Best Practices tools that will be presented respectively as shown in Figure 2.

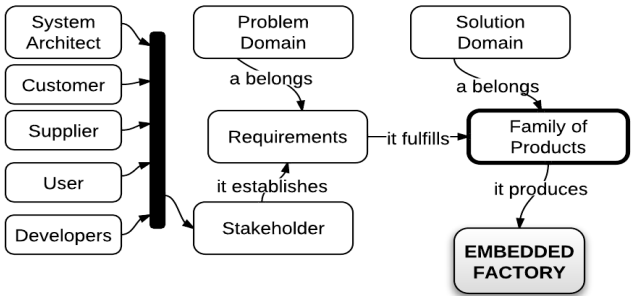

Figure 3 – Description of Family of Products

The flowchart at Figure 3 presents a division between the Problem Domain and the Solution Domain.

The Problem Domain is determined by the aggregation of requirements from the stakeholders and the Solution Domain is the Family of Products that the engineering team will develop in order to fill the needs of customers pointed by the Problem Domain.

It is extremely important that the Family of Products be determined in accordance with market expectations. For this

reason, it shall be systematically studied encompassing the knowledge of the experienced staff from all segments of the business.

EMBEDDED PRODUCT LINE

EPL is a set of applications with similar functionality and specialized to a particular area sharing a common base in order to address the variability in end platforms, that is, a EPL can be assumed as a group of products that are closely associated in the functionality, that are sold to the same group of customers, that are promoted through the same kind of dissemination. [4]

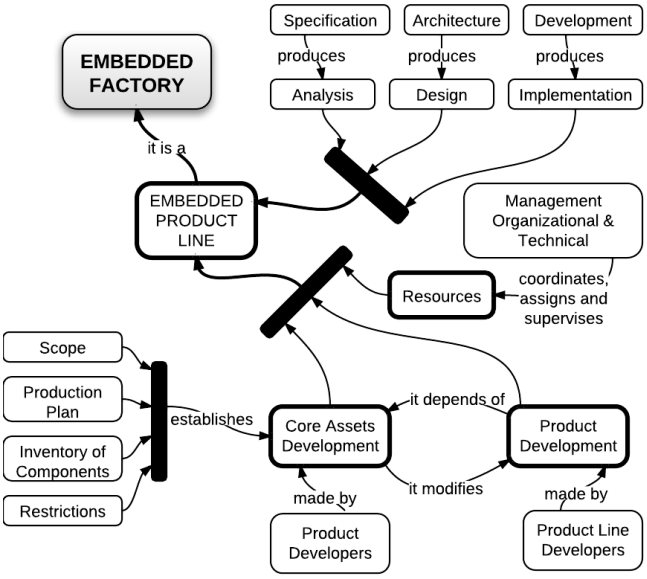

Figure 4 - Concepts of Embedded Product Line

Adopting this concept as shown in the Figure 4, it is necessary to separate the Product Development from Core Assets Development but both shall be managed by the same technical manager.

- **Core Assets Development:** This team is responsible for the development of generic resources, which can be used on any product of the same Family;
- **Product Development:** Mainly consists of assembling the assets developed or stored by Core Assets Team, creating products allowing the best fit to the market requirements;
- **Management:** Is responsible for the coordination and overseeing providing the achievement of the EPL including all technical and organizational necessities.

CONCEPT OF ECONOMY

The model of Supply Chain is used by any organization that produces goods or services. The automotive industry is not out of this premise, but normally it is used only to market the product previously developed and not as a part of the development practice. [3]

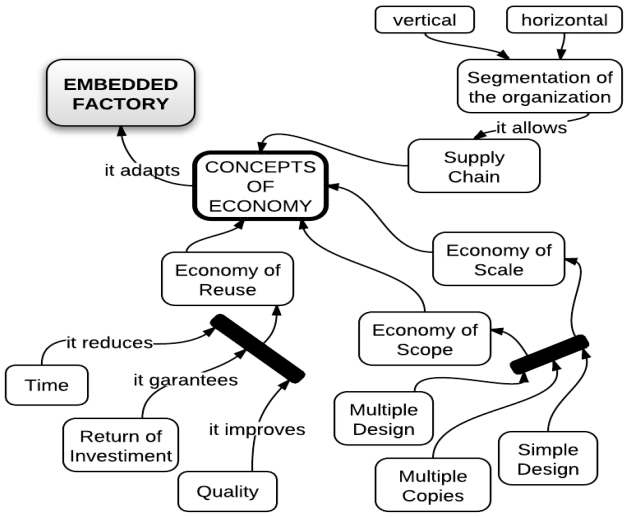

Figure 5 - Economic Concepts of SF

As shown in the Figure 5, the EF can be partitioned vertically and horizontally, in order to delegate tasks to external suppliers, creating Supply Chains for the embedded systems development.

The reuse is applied as a part of the Economic Concept, because it is the key to decrease significantly the Time-to-Market and guarantee the product quality at the same time.

It is important to highlight that the reuse does not provide only time reduction, but the cost of the project is decreased because of engineering effort reduction.

Moreover, must be considered that the Return of Investment is enhanced, because of the focus on the patterns definition. The reuse makes the economic results considerably quicker, thus supporting the *Scale and Scope Economies*.

- **Scale Economy:** Can give the opportunity of the multiple instances of a simple and single design;
- **Scope Economy:** Occurs when multiple but similar projects and prototypes are manufactured together more than independently.

BEST PRACTICES

Best practice is the merging of key ideas like:

- Adopt MISRA-C Rules in order to keep the code robust and reusable;
- Use SysML to accomplish the Model-Driven Development (MDD) for software, hardware, production and all other part of the system that can be modeled;
- Use Computer Applications for Requirements Management, keeping the care with each requirement of the stakeholders;
- Take care of V&V from the beginning of the project, in order to guarantee that the validation process will be robust when the product be prepared for;

- Apply software techniques for Errors Handling, making possible to follow and solve software or hardware problems thru error logging.
- Adoption of Scrum, Agile, XP or other team working organization method;

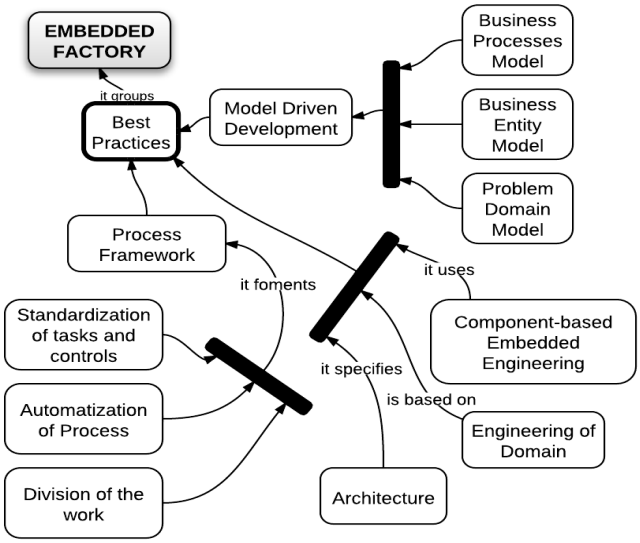

Figure 6 - Best Practices in Software Development

As seeing in the Figure 6, it is important to keep standardization of tasks and controls, try to make the process automatic and to make a good division of the work in order to foment the Process Framework.[3]

SUMMARY/CONCLUSIONS

The EF can contribute with the opportunity to reach economical and technical improvements, considering that the EF is an approach to make the engineering knowledge organized, keeping the lessons learned successfully.

The idea to make parallel development of Software and Hardware Assets is extremely important to a company who desires to win in the market race.

The approach of EF provides important contributions to professionalize and matureness of the Embedded Systems Development business, building an effective and well-organized process that can provide a powerful combination of suitable infrastructures, features, and managerial guidelines.

The EF is an important role towards the goal of competitiveness with better Time-to-Market and faster ROI, parallel development of different products from the same family, standardization of the working process, improved assertiveness in costs and time determinations, reuse of development.

It is important to consider that the EF helps in the specification of the components because of the communality between products, giving a more attractive price in greater orders.

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DEFINITIONS/ABBREVIATIONS

ECU – Engine Control Unit
EF – Embedded Factory
EPL – Embedded Product Line
MDD – Model-Driven Development
ROI – Return of Investment
SF – Software Factory
SysML – Systems Modeling Language
V&V – Verification and Validation