# Towards Requirements Engineering Process for Embedded Systems

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**Abstract.** This paper presents an overview about a Brazilian research towards requirements engineering process for embedded systems. The scientific contributions reported throughout the paper are concerned to templates, guidelines and tools developed during the last four years. These artifacts can help to narrow the existing gap between hardware and software embedded system teams. We brifely describe two requirements specification templates, named TERASE and CAMA, and one requirements elicitation guide, named GERSE which is supported by a software tool called Zaki.

Keywords: Embedded Systems, Requirements Process, Requirements Template and Guidance

## 1. Introduction

In the last two decades the industry of consumer goods has witnessed a huge increasing of Embedded Systems (ES) applications. This kind of system has been widely used, such as in the areas of entertainment products, medical devices, automotive systems, avionics, industry process control, telecommunication devices and others. Currently it is very rare to find any electronic device that is not controlled by ES.

ES is a computing system specially designed to monitor or control a physical device. This computing system usually receives input data from sensors, it processes these data using microcontrollers or microprocessors and sends the results to user interfaces and/or actuators [3]. Software developed to ES, named firmware, is highly coupled to the hardware designed to the controlled devices.

This paper reports research efforts focused to improve the ES development particularly addressing the issues related to requirements elicitation and specification of embedded systems.

This paper is organized as follows: in the section two the objectives of the research are commented; in the section three the main scientific contributions are presented; section four concludes the paper; and finally in section five ongoing and future works are pointed out

## 2. Objectives of the Research

The general objective of the research presented in this paper is to propose a requirements engineering process for embedded systems which will improve the development of such systems and their general quality specially diminishing the existing gap between hardware and software ES teams. In order to achieve this objective the following goals should be developed:

- To identify the main flow of embedded systems development process and to map the relevant process aspects that influence the ES requirements definition.
- To build an ES conceptual model to manage stakeholders, system environment, high level requirements, embedded software requirements, hardware requirements, and communication interface requirements.
- To build guidelines and templates to support ES requirements elicitation, modeling, specification and validation.
- To build integrated software environment to support the use of proposed guidelines and templates.

## 3. Scientific Contributions

The research reported in this paper has started in 2009. The first stage of the research was to identify how ES practitioners in Brazil were approaching requirements during the ES development process. The goal of this field research was to know the state of practice of requirements engineering for ES in Brazil. Professionals that have worked in several industrial segments developing ES were invited (53 ES practitioners answered a questionnaire), the most of them were professionals working in industries in São Paulo state, and the main segments covered in this research were: automotive systems, industrial automation, home appliance, domotics, medical devices, telecommunication and entertainment [5].

Some results from this field research are showed as follows: (i) the most part of the ES practitioners have education on engineering courses (67%) and just 33% have education on computer science courses; (ii) 54.9% revealed that they did not use any organized methodology to elicit requirements; (iii) 41.2% of the ES practitioners that used some requirements elicitation methodology stated that the adopted requirement procedures were not stable inside the organization; (iv) the most cited requirement elicitation techniques were: existing documentation analysis (26%), interview (19%), e-mail exchanging (18%), market analysis (17%), questionnaire (15%) and JAD – Joint Application Development (2%).

It was possible to identify the lack of templates and guidelines that addressed ES practitioner's necessities concerned to requirements elicitation and specification based on the field research results. In order to address these necessities we have developed the following artifacts:

- TERASE: template for environmental requirements specification of embedded systems (TERASE is a Portuguese acronym to "Template para Especificação de Requisitos de Ambiente em Sistemas Embarcados");
- CAMA: template for requirements specification of communication interface among ES physical components based on CAN protocol (acronym is formed by the words CAN, Martins and Almudi);
- GERSE: requirements elicitation guide for ES (GERSE is a Portuguese acronym to "Guia de Elicitação de Requisitos para Sistemas Embarcados");
- ZAKI: software tool to support GERSE activities.

In the next sections some details about each proposed artifact are introduced and briefly commented.

### 3.1 TERASE

The goal of TERASE template is contribute to improve the ES requirements specification particularly focused to the environmental requirements of the ES [4]. Environmental requirements are classified as non-functional requirements and they should be specified according to physical features where the ES will be deployed.

Software development teams usually have to build software according to hardware specifications defined by hardware engineers, software teams need detailed information about environmental variables and physical devices that will capture and control the system. TERASE works as facilitator to improve the communication between hardware and software teams. A complete requirements specification to describe the ES physical environment must include:

- Environmental variables
- Input devices (sensors)
- Output devices (actuators and users interface devices)
- Microcontrollers

For each one of these elements it was proposed a requirement specification card. The cards help the hardware team to record the necessary information to the software team supporting the ES requirements elicitation and specification process.

### 3.2 CAMA

In the construction of embedded systems, the software starts being developed when the hardware is already in a very advanced stage of development. The hardware design tends to be dominant due to having a major cycle of development, being more

stable and requiring logistical dependence on external partners, such as suppliers and outsourced developers. There is not, so far, an appropriate methodology to help developers to specify the requirements to automotive embedded systems, causing a large gap between designers from hardware and software areas, especially in the early phases of structuring the design [8]. One of the possibilities that CAMA Template offers is the integration between developers through a resource that provides easy communication channels between the hardware designers and software engineers.

CAMA Template is used to specify the relevant and special aspects of the automotive embedded communication systems network that use CAN protocol in exchanging information [6]. The template is structured in Figure 1. The ES features managed by CAMA are organized using specification cards.

An automotive embedded system was chosen for the study case to have its requirements specified through the proposed template. The study was based on a finished specification from a major international car manufacturer with a plant in Brazil, with a large insertion in automotive Brazilian market.

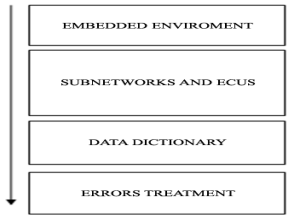


**Fig. 1.** – CAMA Template's General Structure

### 3.3 GERSE

The main goal of the proposed guide is to help ES engineers during the requirements elicitation process. GERSE leads ES engineers during the elicitation process offering a set of activities that addresses the ES main features [7]. Using GERSE, ES engineers can manage the requirements elicitation process in an organized way. The proposed guide helps the requirements definition allowing its complete specification for products based on embedded technology.

GERSE is divided into two phases, named pre-phase and main phase, which are organized in seven categories. These categories are organized in 46 activities, which are responsible to generate the artifacts that will compose the ES requirements. Each activity produces at least one artifact that can be both a document describing a specific feature of the product or a diagram modeling any specific feature. The pre-phase activities will help the ES engineers to make the transition from the high level requirements to technical requirements. Figure 2 shows a GERSE overview presenting the categories proposed to each phase.

GERSE documentation were sent to four ES engineers to evaluate the proposed guide, the evaluation was performed through survey. The ES engineers expertise was in automotive systems, medical devices and entertainment areas. All ES engineers

evaluated GERSE as a useful guide for ES requirements elicitation stating that such guide is easy to use and contributes to increase the ES development quality.

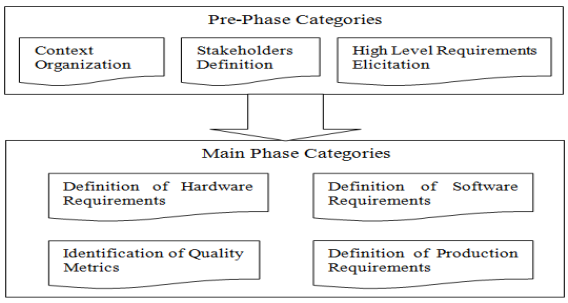


**Fig. 2.** Phases and categories supported by GERSE.

### 3.4 ZAKI

The adoption of any software process can be facilitated by the use of computer support. In this sense, a tool called Zaki was developed to support GERSE activities and the requirements elicitation process for embedded systems.

Zaki tool is divided into two modules, according to GERSE phases - pre-phase and main phase - supporting activities like requirements elicitation, analysis and management for embedded systems. Zaki tool was developed using .NET platform - C# language- and the SQL Server database.

During the pre-phase, Zaki tool supports functionalities related to manage information about project guidelines and main product features, development organizational impact and target audience. During the main phase, Zaki tool is divided into three modules: Definition of Hardware Requirements, Definition of Software Requirements, and Identification of Quality Metrics.

## 4. Conclusions

The communication problem between hardware and software teams is a great challenge to be overcome in the context of ES development [1][2]. Software engineers need to receive a precise and complete requirements specification covering all aspects of hardware and environment where ES will be executed. A significant part of such specification is built by hardware engineers. Failures and mistakes in the communication process between hardware and software teams have strong impact in the final cost and schedule as well as in the general quality of the system.

In this paper we presented some research results that addressed the communication problem during ES development. These results consisted of two requirements specification templates – called TERASE and CAMA - and one requirements elicita-

tion guide – called GERSE – both designed to improve the communication among ES stakeholders. GERSE is supported by a software tool called Zaki.

## 5. Ongoing and Future Work

Currently this research group is working to improve Zaki tool to support all GERSE activities as well as adjusting some GERSE activities to make them easier to be used by requirements engineering teams in the ES context. GERSE is also being tested in the context of critical embedded systems specifically for an embedded system to control a medical device (insulin infusion pump). The main future works are listed as follows:

- To test GERSE in larger ES project;
- To integrate TERASE, CAMA and GERSE in a same software environment;
- To test and adapt the proposed artifacts in the context of robotics systems;
- To improve the templates and guidelines proposed to support requirements specifications for adaptive embedded systems;
- To start research efforts focused to requirements gathering in the context of cyber-physical systems.

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