

Embedded System Design: An Overview of Brazilian Development

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Abstract— Brazil, like other emerging countries such as China and India are increasing significantly their importance as global players. The Brazilian economic relevance gains more importance with its economic growth and industry expansion. This economic growth also reflects on embedded systems design that expands following the market demand for new products. The Brazilian developments are ubiquitous in different areas: industrial automation, automobiles, home appliances, electronic consumers etc. A statistical survey was conducted to evaluate the embedded system development in Brazil, to identify the developer's profile and the main characteristics of embedded projects. The main results indicate that Brazilian embedded developer is generally young, no older than 35 years old and has a maximum of 10 years of embedded system design experience. They also show that embedded project developed in Brazil, are commonly linked to new products, last more than 6 months and usually are delayed considering the initial schedule.

Keywords—*Embedded Systems; Embedded Development; Embedded Software, operating systems*

I. INTRODUCTION

Brazil, like other emerging countries such as China and India are increasing significantly their importance as global players.

In the last years, the national industry expansion and the economy growth are leveraging Brazilian economic relevance in global market.

This economic growth also reflects in Brazilian embedded system development in the industry, due to the market demand for new and more efficient products.

The global companies that used to develop electronics outside the country and “tropicalize” products, are creating, nowadays, development centers on Brazil to design products for internal and external market. Furthermore, small and medium national companies are expanding their importance, developing technology and exporting products.

The Brazilian embedded system designs are ubiquitous in different areas: industrial automation, automobiles, home appliances, avionics, electronic consumers etc.

In this context, the presented work aims to evaluate the embedded system design in Brazil, identifying the developer's profile and the main project characteristics.

II. RELATED WORKS

Today, embedded systems are ubiquitous in different areas, from the industrial automation to home automation, from medical instruments to automobiles, from mobiles to washers. It is difficult to find activities that do not make use of these devices in our daily life [5] [7].

Embedded systems are composed of hardware, software and in some cases, of additional mechanical parts. Generally, these devices perform dedicated functions and share common properties like limited resources (memory, weight, space and energy), real-time requirements, multitasking, high complexity and resource sharing [2] [5].

Henzinger and Sifakis [4] say that the embedded system design requires a holistic approach, using consistently and in an integrated manner the paradigms of hardware design, software design and controls theory.

According to Ganssle [3], the engineers are balancing requirements of quality, schedule and functionality when are developing a product. An unbalance on these requirements usually can jeopardize the product development.

A survey, developed in 2006 by the *EETimes* and *Embedded System Design* publications [9], shows that 52% of projects are delivered with delays, with a tardiness average of 4.3 months. The data also shows that 61% of the developers work concurrently on more than one project and the average duration of projects are 14 months.

The 2006 survey [9] demonstrates that the majority of embedded systems designs are related to changes in existing products, which represents 56 % of developments.

Embedded systems usually are built using microcontrollers that are developed focused on size, performance, energy consumption or cost [1]. According to Mokhoff [6], the microcontrollers market shall exceed US\$ 12 billion in 2010, with revenue growth of 11%, leveraged mainly by automotive industry. The great microcontroller suppliers are Renesas, Freescale, NEC, Infineon, Fujitsu and Microchip, which together represent 60% of market share.

Microcontrollers usually support 4, 8, 16, 32 and 64-bit processing. Fig. 1 shows the microcontroller market segmentation based on data from 2004 [8]. Fig. 2 shows microcontroller usage in embedded projects, based on data from a 2006 survey performed with developers [9].

Beside the better performance of 16 and 32-bit platforms, the 8-bit microcontrollers still answer for substantial percentage of global microcontroller sales volume. The main reason is the cost effectiveness of these devices. Japan still the great market for 8-bit microcontrollers. However a huge growing is identified in emerging markets like India and China [8].

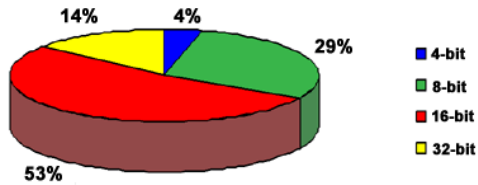


Figure 1. Microcontroller market segmentation – 2004 [8]

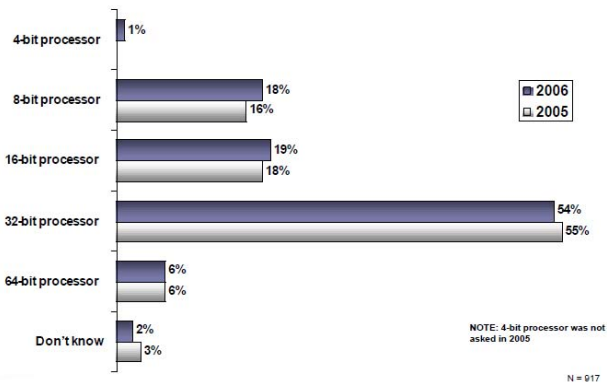


Figure 2. Project microcontroller utilization – 2006 [9].

Embedded system projects usually use C and C++ languages for software design. In 2006, according to a survey developed by the *EETimes* and *Embedded System Design* publications [9], the C language has been used in 51% of projects and C++ in 30%.

Code reuse is other characteristic of embedded software design. About 88% of projects reuse some kind of code, as showed in [9]. Furthermore, it is also demonstrates that 71% of embedded designs have an operating system, real-time operating system or kernel. Less than 30% of embedded software is developed without an operating system. The main reasons why an operating system is not used are: no need of project, processing consumption, memory consumption and cost.

In terms of age range, 60% of embedded system developers are 35 to 49 years old and 63% have more than 10 years of experience [9].

III. METHODOLOGY

In order to evaluate the Brazilian embedded system design, a statistical survey was developed to take a snapshot of developer's profile, identify the project and software design characteristics and verify the operating system usage.

The survey has been performed with developers from different industry areas: automotive, home appliances, industrial automation, commercial automation, medical equipments, consumer electronics and aerospace.

The developers were contacted through e-mail and were invited to answer a questionnaire.

The developers were asked about:

- Job position
- Age
- Undergraduate course
- Graduate course
- Embedded System design experience
- Number of concurrent projects worked on
- Kind of project (New product, Change on field products, innovation, quality problems, research)
- Project duration
- Project timeliness
- Project Challenges
- Processor Architecture (4-bits, 8-bits, 16-bits, 32-bits, 64-bits etc)
- Code language (Assembly, C, C++ etc.)
- Code reuse
- Operating systems usage
- Reason for use or not use an operating system.

In order to ensure research secrecy and suitability confidence, the survey was stored in a server, which the participants could access through a link received by mail, without sending any kind of personal information.

Moreover, all survey questions did not request any kind of participant's personal data, company's information or business sector.

These guaranteed a unique and exclusive scientific focus to the research, without any commercial or industrial interest, preserving the respondents.

The data received were stored in a spreadsheets and post processed using Microsoft Excel. The processed data are then presented in graphics and tables, making easy the results comprehension and readiness.

IV. RESULTS

Forty participants answer the questionnaire. The data were collected from September 28th to November 5th of 2010.

A. Developers' Profile

The survey has been distributed to a variety of persons with different roles in the embedded system design. It has created a heterogeneous sample space that brings to the research different visions of whole embedded system development process. There are among the participants: development engineers, managers of development teams and project leaders.

The developers represent the majority of participants, totalizing 80% distributed among software engineers (54%), hardware engineers (13%) and researchers (13%). In the survey the job position was self defined by the participants.

According to collected data, was observed that developers are composed mainly by young people. It was found that most of the developers (54%) are in the age group between 26 and 30 years old and that approximately 90% are not older than 35 years old. Hardware and Software developers stand out among the youngest while the project leaders and development team managers stand out among the oldest.

The participants involved in embedded system design are mostly engineers, representing 80% of respondents, great part with an Electrical Engineer degree (64%). Only 5% of participants are graduated in Computer Science. This fact probably is caused by the close connection between software and hardware, usually developed together, more familiar to electrical engineers. Furthermore, most of computer scientists are absorbed by the Information technology (IT) market and by the personal computer (PC) software design.

It is necessary to emphasize the participation of mechatronics engineers, representing 13% of respondents. These engineers are increasing their participation in embedded design due to the link between mechanical and electrical components mainly in automotive, home appliances and industrial automation segments.

Fig. 3 shows the distribution of respondents among undergraduate degrees.

It is interest to note that only 46% of respondents have a graduate level. Among the graduate courses stands out the Master of Science degree, cited by 28% of participants. However, this number should increase, mostly by the market competitiveness and by the great appreciation of masters and doctors by the industry. In the questionnaire, several participants have declared coursing a graduate course.

The survey results indicates that 87% of developers has no more than 10 years of experience in embedded system design and that 51,3% has no more than 5 years of experience. Considering the boundary of 20 years of embedded system design experience, 100% of respondents are encompassed. The project leaders and the development team managers stand out among the more experienced.

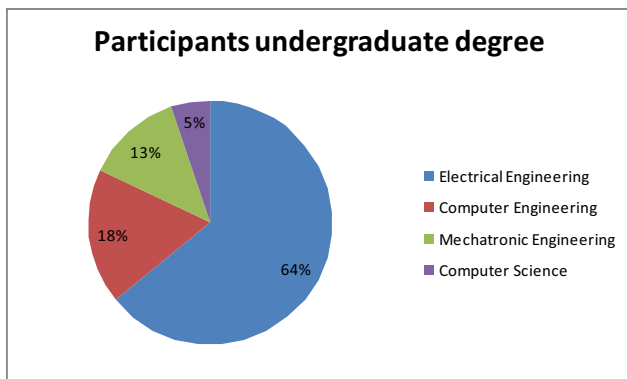


Figure 3. Survey participants undergraduate degree.

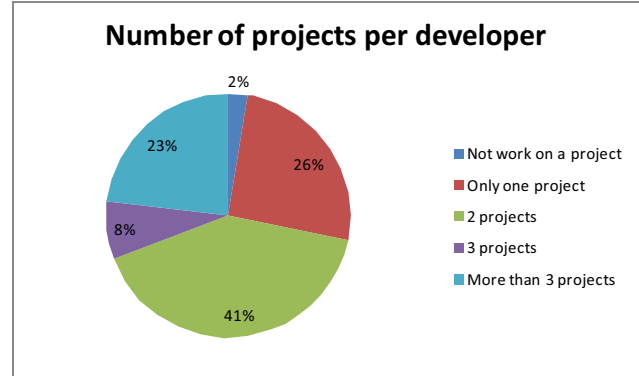


Figure 4. Number of projects per developer - Participants distribution.

These data and the age data, show a common trend verified in Brazilian companies, mainly with engineers, that begin their careers directly connected to development and then migrate to administrative areas.

The developers, according to survey, usually conduct 2 or more projects concurrently, with about 25% working on more than 3 projects at same time. The majority of developers work on 2 projects at same time, which represents 41% of respondents. Fig. 4 shows the number of products conducts by the participants.

These results show that the market requires good routine management skills from developers and also indicates that some of them may work overloaded.

Comparing the results of this work with the data of a research with subscribers of *Embedded Systems Design*, *Embedded Systems Conference*, *EE Times* and *Embedded Systems Europe* publications [9] is noted that Brazilian developers are less experienced, younger and work in more projects concurrently.

B. Embedded project characteristics

The Brazilian embedded system designs are mostly linked with new products, which represent 66.7% of projects. The survey results also highlights the updates in current field products (improvements, maintenance etc) that represent 12.8% and innovation products that respond for 10.3% of projects. The distribution of project types is described on Table I.

These projects commonly last more than 6 months, 35% have duration between 6 months to one year and about 30% last more than 1 year. Fig. 5 shows the project distribution among the time intervals of project duration.

Results show long cycles of development that impact directly in product time-to-market. The time-to-market and the cost are indicated as the main challenges on embedded system design by the respondents. Both represent 25% of answers. Other challenges cited are innovation and quality.

The research shows that project challenges are constantly connected to the triad schedule, quality and functionality described by *Ganssle* [3]. The cost and innovation reflects the functionality request from embedded systems.

TABLE I. PROJECT DISTRIBUTION AMONG THEIR DIFFERENT TYPES

Project type	% of projects
New product development	66,7
Product updates (Improvement, maintenance, etc.)	12,8
Quality improvements	5,1
Innovation	10,3
Research	5,1

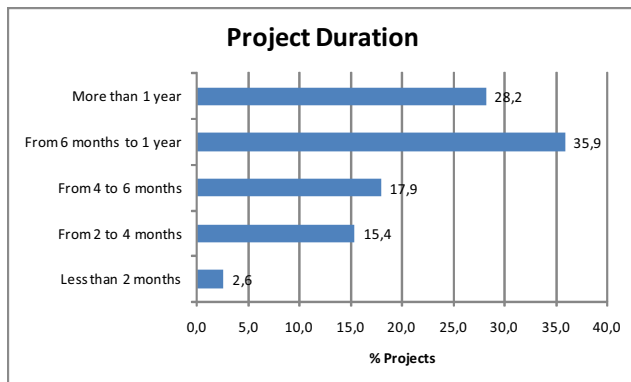


Figure 5. Embedded project duration. Percentual distribution among duration time intervals.

These challenges are also linked with consumer loyalty that uses look for quality, innovation, cost-benefit, in the correct time (time-to-market).

The survey data, also demonstrate, that most of embedded projects in Brazil are delayed considered the original schedule. About 40% are delivered more than 3 months late and 30% had a delay of 1 to 3 months. Only 23.1 % of the projects follow the original schedule. These delays are usually caused by changes in specification, common in embedded systems design, and also by the large number of concurrent projects conduct by the developers.

Comparing these results with the 2006 survey [9], the Brazilian embedded projects are more focused on new products, have shorter cycles of development but their schedules are commonly delayed.

The data from 2006 [9], show that usually the embedded design are focused on current products in the field (56%), last more than 1 year (50%) but follow more the schedule being delivered according to deadline (42%) or with delays of 2 months (25%).

The Brazilian embedded systems are mainly developed using 8-bit microcontroller, present in 41% of the projects. The 16 and 32-bit microcontroller have also important participation on developments, each representing 26% of projects. Fig. 6 shows the projects distribution among microcontroller architectures.

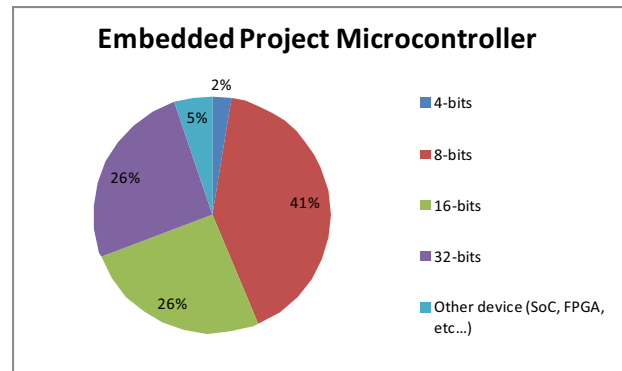


Figure 6. Microcontroller architecture distribution among the embedded projects.

It is possible observe a common characteristic of emerging countries development by these data: the cost pressure. In this sense, the 8-bit microcontrollers arise as the best alternative for embedded system design.

Among the main microcontroller suppliers are the American companies such as *Freescale*, *Microchip* and *Texas Instrument* that represent 30.6%, 22.2% and 19.4% of Brazilian projects, respectively.

Comparing the results with 2006 survey data [9] the Brazilian developers usually use small microcontrollers, valuing the cost during their selection. The main suppliers on both surveys are the same.

The Brazilian embedded software is built, mostly, using C language that responds almost for all developments (79.5%). The C++ usage is around 10%, while the Assembly language and Java each representing 2.8% of projects. Fig 7 shows the project distribution among the programming languages.

The survey data, also show that the code reuse is common but in small proportions. It occurs in 92% of projects. However, only 28% of developments reuse more than 50% of existing code.

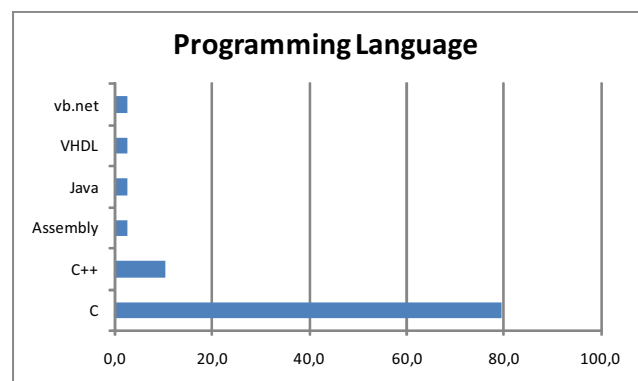


Figure 7. Programming languages used on embedded software development.

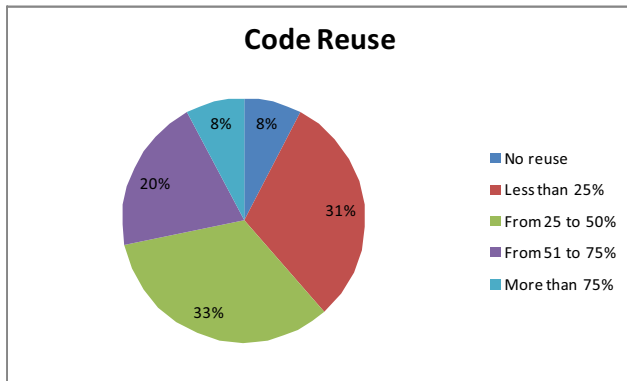


Figure 8. Code Reuse rate during embedded software development.

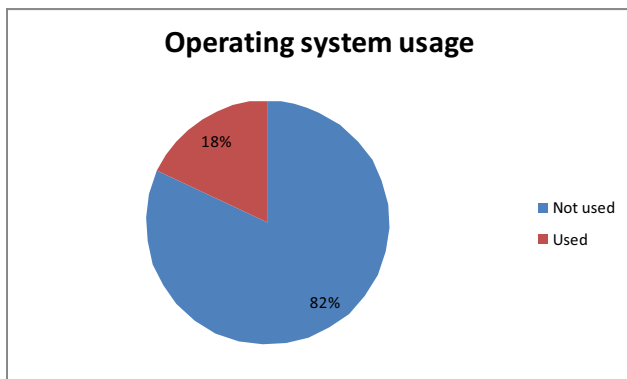


Figure 9. Operating system usage on embedded software development.

These results demonstrate that more than 50% of products code shipped are created from scratch. This practice tends to increase the project duration and to reduce the robustness, since tested code have more reliability and hardly have big issues that can jeopardize the project. Fig. 8 shows the project distribution among ranges of code reuse.

According to survey data, only few embedded software developments in Brazil (18%) use an operating system. These developments are concentrated more in 8-bit microcontroller platform than in the 16 and 32-bit platforms. However, this happened due to the great usage of 8-bit microcontrollers. Fig 9 shows the usage of operating system in Brazilian embedded system design.

Evaluating these results comparatively with 2006 research data [9] is verified that Brazilian developments use less operating system. Data from 2006 indicates that 71% of projects use some kind of operating system, real-time operating system or a kernel. However, this fact is explained by the larger usage of 32-bit microcontrollers by 2006 survey participants. In these microcontrollers the operating systems are more suitable.

The main reasons for operating system usage are the real-time requirements, need of multitasking management and development speed up. Robustness is also presented as a reason for operating system usage. On the other hand, the reasons for non-usage are unnecessary use, the memory consumption and company strategy.

These data is similar to that obtained in 2006, by a statistical survey performed with subscribers of *Embedded Systems Design*, *Embedded Systems Conference*, *EE Times* and *Embedded Systems Europe* publications [9]. It is important to highlight that many Brazilian describe the company strategy as a reason for no usage of an operating system, fact not identified in that study.

V. CONCLUSIONS

The research results show that Brazilian embedded developer is generally young, no older than 35 years old and has a maximum of 10 years of embedded system design experience. Usually has an Electrical engineering undergraduate degree, do not have a graduate degree and works on more than 1 project at same time.

A migration tendency of more experienced engineers to administrative areas like project leadership and team management is observed. The increase of developers coursing a Master of Science degree is also verified.

The embedded projects developed in Brazil, are commonly linked to new products, lasting more than 6 months and usually are delayed considering the initial schedule. The time-to-market and the cost are some challenges of the Brazilian projects. It is observed that most of the challenges are connected to consumer loyalty that requests for quality, innovation and cost-benefit on the right moment (time-to-market).

The developments are dominated by 8-bit microcontrollers, although the 16 and 32-bit architectures are considered as significant players. The cost is the major factor on microcontroller selection.

Most of Brazilian developments usually use the American suppliers: *Freescale*, *Microchip* and *Texas Instrument*.

The embedded software is written mainly using C language and reuses less than 50% of old code, what may affect the project duration and robustness, since the code previously tested has great reliability and less chance to have a gross failure. The results also show an obsolescence trend of Assembly language.

In respect to operating system, only 18% of Brazilian projects use an operating system, what is justified by no necessary usage of the project, consume of memory and company strategy. The need of multitasking management, the real-time requirements and development speed up are described as the main reasons for it uses.

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