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# A study about HCI in practice of interactive system development using CMMI-DEV

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## ABSTRACT

Human-Computer Interaction (HCI) community has proposed many methods, techniques and standards for the development of interactive systems. Despite the great recognition of many of these approaches in academia, little is known about the state of practice in industry. To what extent are they known and used, while using a defined software process, to develop interactive systems? What is their level of use compared to software engineering approaches? This paper presents a study that we have conducted to answer these questions. This study is developed on top

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of one of the widest used software process improvement model: CMMI (Capability Maturity Model Integration). This paper presents the planning of this study, the research protocol and some initial results.

## CCS CONCEPTS

• **Human-centered computing** →; *Empirical studies in HCI*

## KEYWORDS

Human-computer Interaction, Interactive systems, Capability Maturity Model, Software engineering

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## 1 INTRODUCTION

Undoubtedly, software process capability and maturity (SPCM) models are reached a large use in industry [14]. These models are collection of software engineering best practices that help organization to improve their process. SPCM models define practices for the development of any kind of system. They do not indicate any specific technique, method, or any specific approach; they describe what should be performed by the developers of software systems who are free to choose the approaches in order to implement the practices. One can suppose therefore that Human-Computer Interaction approaches should naturally be applied when SPCM models are used in the development of interactive systems. Based on this belief and taking profit of the large use of CMMI in industry, this paper presents a study that aims to investigate to what extent the HCI approaches are known and used by software developers. Moreover, to better analyze the results in a complete way considering the software development view we have also investigated if the developers know and use HCI approaches as they know and use Software Engineering approaches.

To that end, we first identified HCI approaches [6-7] adequate to support practices of the CMMI for development [2] based on HCI experts' opinion. After that, we looked in the literature software engineering approaches used to support the practices. Then we defined a specific research protocol and a questionnaire (survey), and we have surveyed enterprises of the top ten

countries that use CMMI according to CMMI Institute<sup>1</sup>. In this paper, we present this research with some initial results from industry.

This paper is organized as follows. Section 2 briefly presents the main concepts of CMMI used in this study. Section 3 presents how we defined the HCI and SE approaches to support the practices of CMMI. Section 4 and 5 present the planning and execution of the study. Section 6 discusses the related works and section 7 presents some final remarks.

## 2 A BRIEF OVERVIEW OF CMMI

In the 1980s, the US Department of Defense (DoD) requested the development of a framework of criteria for evaluating its software providers. They financed the Software Engineering Institute (SEI) that presented in 1991 the Capability Maturity Model (CMM) [10]. In 2001, SEI proposed a new version of this model, the CMMI-DEV (Capability Maturity Model Integration for Developers), which encompasses the best practices of different models. The CMMI-DEV is a process model (best practices repository) for the realization of any type of product (or system). It is however in the development and maintenance of software that it is most used. It is currently in version 1.3 [2].

The best practices of CMMI-DEV are organized in-group to address specific goals of different process areas. The CMMI-DEV v1.3 presents 22 process areas that cover engineering, support, project and process management activities. The engineering process area is directed related to the development and evaluation of software systems (our interest in this paper) that are: Requirements Development, Technical Solution, Product Integration, Validation and Verification. They encompass 40 specific practices (SP) grouped in 14 specific goals (SG). To illustrate, an example for the *Requirements Development* process area is the *SG1- Develop Customer Requirements* composed of two practices: *SP1.1 Elicit Needs*; *SP1.2 Transform Stakeholder Needs into Customer Requirements*.

Moreover, CMMI-DEV uses levels to describe an evolutionary path for an organization that wants to improve its processes. Two types of levels are defined for software process improvement: (i) capability levels, improvement of one or more chosen process areas; and (ii) maturity levels, improvement of a set of pre-defined process area. Maturity levels are the most applied in industry organizing the process areas in a staged representation where each level is composed of several process areas. The staged representation has five maturity levels (1-5). Process areas of engineering are in the Defined level (3), which means the organization uses a defined process to develop its systems.

## 3 SUPPORTING CMMI-DEV WITH HCI APPROACHES

To apply the best practices of CMMI-DEV, software developers should use the existing workbench of techniques, methods, standards and methodologies. From this idea, our first

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<sup>1</sup> <http://partners.cmmiinstitute.com/find-partner-organization/>

**Table 1: HCI categories x Examples**

<i>HCI Category</i>	<i>Examples</i>
Task Analysis Methods for HCI	CTT (Concur Task Tree); K-MAD (Kernel of Model for Activity Description); HTA (Hierarchical Task Analysis); SADT (Structured Analysis and Design Technique); GTA (Groupware Task Analysis).
Evaluation methods for HCI review	Heuristic evaluation; Cognitive walkthrough; Groupware walkthrough.

research activity was to scan all engineering specific practices from CMMI-DEV to identify where it was indicated that HCI issues should be taken into account.

To analyze the documentation, we initially seek explicit citations of HCI engineering by looking for: (i) HCI keywords (for example, external interface, end user, prototype); (ii) examples of techniques or methods of HCI (e.g. end-user task analysis, HCI models); and (iii) examples of work products (e.g. interface design specifications, user manual). Then, we looked for citations that were not directly related to HCI Engineering but that we could interpret in benefit of the use of it. We classify this information as implicit citations. Explicit and implicit citations were highlighted in the text and reviewed together in a final reading.

With all the identified citations and considering the literature of HCI (for example, [3, 11, 12]) and existing reviews of HCI approaches that support system development (for example, [4,5,13]), we proposed an initial set of approaches organized in 10 HCI categories. For each HCI category, we included examples of methods, techniques, and standards. Table 1 presents some categories and their examples of approaches. Considering the identified citations in each practice, we associated each category as support for the accomplishment of the practices. For example, "Task Analysis Methods for HCI" was proposed as approaches to support the specific practices (SP1.1 and SP1.2) of the specific goal 1 of requirements development previous presented. In total, we had 33 propositions supported by HCI categories that were related to specific practices.

With this initial set, we interviewed twenty HCI experts (19 years of experience in average) well known in the HCI community. They were asked to analyze all propositions presented in a form (see example in Figure 1) and answer about their level of agreement justifying it. Each interview took in average 1.5 hours. The experts used the material to discuss and explain the use of several approaches in the development of interactive systems based on their own experience in academia and industry (14 experts declared have worked in the industry).

Process Area and Specific Goal (SG)	Specific Practice (SP)	Methods, techniques, standards and patterns of HCI	Answer			Justification
			I agree	I partially agree	I don't agree	
Requirements Development <i>SG1 Develop Customer Requirements</i>	SP1.1 Elicit Needs	<b>Task Analysis Methods for HCI</b>			x	"Task Analysis is further modeling activity than an elicitation activity."
	Elicit stakeholder needs, expectations, constraints, and interfaces for all phases of the product lifecycle.	Examples: CTT, K-MAD, HTA, SADT, GTA.				

**Figure 1: Simplified extract of the questionnaire (adapted from [7])**

**Table 2: HCI categories x SE categories**

#	HCI Categories	SE Categories
1	Techniques to identify user needs	Techniques to identify needs
2	Techniques to identify user and organizational requirements	Techniques to identify requirements
3	Task Modeling	Software Modeling
4	Standards and Guidelines for HCI design	Standards and Guidelines for design
5	Prototype for HCI requirements	Prototype for requirements
6	Techniques to validate HCI requirements	Techniques to validate requirements
7	Architecture patterns for HCI	Architecture Patterns for SE
8	Design patterns for HCI	Design Patterns for SE
9	Techniques for interaction modeling	Interaction modeling for SE
10	Techniques for HCI documentation	Techniques for final documentation
11	Iterative and Evolutionary Prototypes (system versions)	Prototype (system versions)
12	Evaluation methods for HCI verification	Verification methods
13	Evaluation methods for HCI review	Review methods
14	Evaluation methods for HCI validation	Validation methods

Considering that we had 20 experts and 33 propositions, we had 660 responses to analyze. In general, we got 59% of agreement, 33% of partial agreement and 8% of disagreements. Analyzing all justifications from the partial agreement and disagreement, we modified the categories and the propositions, when it was applicable. As a final result, we evolved to 14 HCI categories (see Table 2) and 39 propositions to support the practices of engineering processes areas. Some categories were renamed and others included. A detailed description of this study can be found in [6-7].

#### 4 PLANNING THE INVESTIGATION IN INDUSTRY

To apply the best practices of CMMI-DEV, software developers should use the existing workbench of techniques, methods, standards and methodologies. From this idea, our first research activity was to scan all engineering specific practices from CMMI-DEV to identify where it was indicated that HCI issues should be taken into account.

Considering the large use of CMMI-DEV and the public information of accredited enterprises to CMMI Institute, we decided to ask to the contact person of these enterprises to what extent they know and use HCI approaches when working in the development of interactive systems. Moreover, we also planned to verify if they know and use these approaches as they know and use Software Engineering (SE) approaches when implementing the practices. To that end, we defined corresponding SE categories to each HCI category considering the well-known literature (see Table 2). We formalized the goal of this study according to [16] as follows: Analyze HCI and SE approaches for the purpose of characterization with respect to know and use of methods, techniques, standards and patterns from the point of view of software developers in the context of interactive system development.

The study was planned to be conducted off-line. A questionnaire was available in a web site being composed of two parts: (1) characterization of participants<sup>2</sup> and (2) survey questions<sup>3</sup> (see extract in Figure 2). In this way the participants (software developers) could answer the questionnaire in their own time and environment, not being monitored. For each category (HCI and SE), participants should answer to what extent they know and use the approaches when implementing the practices, using a Visual Analogue Scale (VAS) [15] – a horizontal line with two anchor points, from “None”(0) to “A lot” (10). The subjects were the contact persons of the associated enterprises to CMMI institute’s database. Considering that our interest is the engineering process areas, we selected only enterprises that had CMMI-DEV equal or greater than 3 (defined level).

<sup>2</sup> <https://surveytesis.000webhostapp.com/survey3/partone.php>

<sup>3</sup> <https://surveytesis.000webhostapp.com/survey3/parttwo.php>

**Table 3: Organizations x Responses**

Country	# Enterprises	# Answers
Brazil	4	4
China	18	0
France	6	2
India	23	3
Japan	5	2
Mexico	7	1
Republic of Korea	7	0
Spain	7	3
United Kingdom	10	0
United States	119	6
Total	207	21

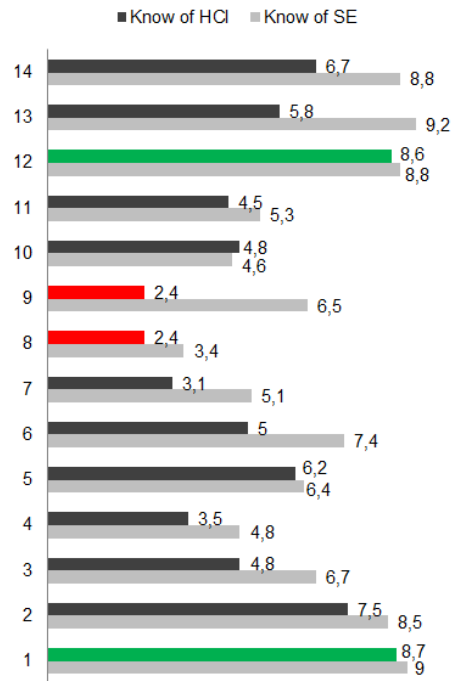
To **analyze** and interpret the data we first computed the mean of the level of knowledge and use of each HCI category answered by the participants (that is the reason for choosing a continuous scale). Moreover, to analyze to what extent the participant know/use the practices related to SE approaches we formalized two hypotheses as follows:

- Null hypothesis  
The software developers know and use HCI approaches as well as they know and use SE approaches when applying the same specific practices of CMMI-DEV engineering process area.  
 $H1_0$ : Know of  $HCI_i$  – Know of  $SE_j = 0$ ;  
 $H2_0$ : Use of  $HCI_i$  – Use of  $SE_j = 0$ ;  
 where  $i$  is each of the HCI categories and its equivalent in SE is  $j$ .
- Alternative hypothesis  
The software developers know and use HCI approaches less than SE approaches when applying the same specific practices of CMMI-DEV engineering process area.  
 $H1_A$ : Know of  $HCI_i$  – Know of  $SE_j < 0$ ;  
 $H2_A$ : Use of  $HCI_i$  – Use of  $SE_j < 0$ .

Please, indicate your level of knowledge (*I know*) and level of use (*I used*) to each one of those methods, techniques, standards and patterns when in the implementation of Capability Maturity models in enterprises you worked.

#	Process Area (CMMI-DEV)	Potential methods, techniques, standards and patterns from Software Engineering (SE)	Potential methods, techniques, standards and patterns from Human-Computer Interaction (HCI)
1	Requirements Development <i>RD SP1.1 Elicit Needs</i>	<p><b>Techniques to identify needs</b></p> <p>Examples (see <b>References</b>), not limited to:</p> <ul style="list-style-type: none"> <li>◆ Brainstorming</li> <li>◆ Interviews</li> <li>◆ Questionnaires</li> <li>◆ Card Sorting</li> <li>◆ Focus Groups</li> <li>◆ Field Studies/Observation</li> <li>◆ Workshops</li> <li>◆ Protocol Analysis</li> </ul> <p><b>Answers</b></p> <p><b>I Know:</b></p> <p>None <input type="text"/> A lot</p> <p><b>I Used:</b></p> <p>None <input type="text"/> A lot</p>	<p><b>Techniques to identify user needs</b></p> <p>Examples (see <b>References</b>), not limited to:</p> <ul style="list-style-type: none"> <li>◆ Brainstorming</li> <li>◆ Interviews</li> <li>◆ Surveys/Questionnaires</li> <li>◆ Card Sorting</li> <li>◆ Focus Groups</li> <li>◆ Field Studies/Observation</li> </ul> <p><b>Answers</b></p> <p><b>I Know:</b></p> <p>None <input type="text"/> A lot</p> <p><b>I Used:</b></p> <p>None <input type="text"/> A lot</p>

**Figure 2: Extract of the questionnaire available in the web site**



**Figure 3: Results by category for Knowledge**

## 5 STUDY EXECUTION AND INITIAL RESULTS

The CMMI Institute's database presents the data of 281 Partner Organizations that implement and evaluate CMMI-DEV from different countries. To reduce the scope, we decided to select the ten top countries in terms of official CMMI appraisals in the last years. Table 3 presents these countries that totalize 207 organizations, our population for this study. The survey request was sent by email with four recalls (6 months). Up to now, we got 21 answers (see Table 3). Considering the confidence level of 95%, as usual recommended, we have 20% of margin of error considering this sample size.

By performing a descriptive analysis we note that about the profile of respondents, 15 participants worked as consultant in the enterprises; 4 were employees; and 2 have worked as consultant and were employees. They have between 9 and 28 years of experience in capability maturity models implementations. About the capability maturity level(s) supported in the implementations, 57% of the respondents have supported implementations in CMMI-DEV level 5, 4 and 3, and 29% declared that have supported only implementations in Level 3.

The participants answered their perception about to what extent they know and use the approaches by considering their experience in different enterprises developing several projects. We computed a total of 1228 enterprises and 5.025 projects. For the data (know and use), we computed the mean of answers (see Figure 3 for knowledge and Figure 4 for use) to each category (see Table 2). Analyzing only the HCI categories we note that the categories 1 and 12 presented the highest levels of knowledge and use. Looking in more detail by country (Figure 5 and Figure 6, we note that Japan is the country with the highest level of knowledge and use. We note also that France has the lowest level of knowledge for category 12 (Evaluation methods for HCI verification) and it is better only than Mexico in terms of use for the same category.

We believe that this result is justified since the approaches exemplified in all categories are quite similar for SE and HCI. In the other hand, categories 8 and 9 presented the lowest level of knowledge and use, probably because the categories from design patterns and interaction modeling for HCI are very recently proposed.

Analyzing the results for SE categories, we note that: (i) the participants declared that they know more the approaches from the categories 1 (techniques to identify needs) and 13 (review methods); (ii) and they used more the approaches from the categories 6 (techniques to validate requirements) and 13 (review methods). As previously explained, the approaches exemplified in category 1 are quite similar for SE and HCI. The approaches from category 13 are related to review methods that are very known and used in SE domain. Similarly, the category 6 presents approaches that are more used in SE domain to validated customer requirements than the approaches from category 14.

The results show that the level of knowledge and use for the category 10 (techniques for final documentation) is higher for HCI than for SE. This category is related to final documentation of the system, and we believe that HCI domain cares about this part because it is related to final

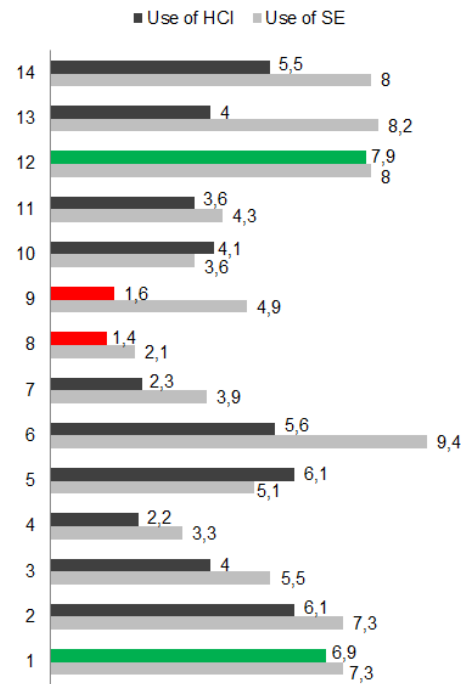


Figure 4: Results by category for Use

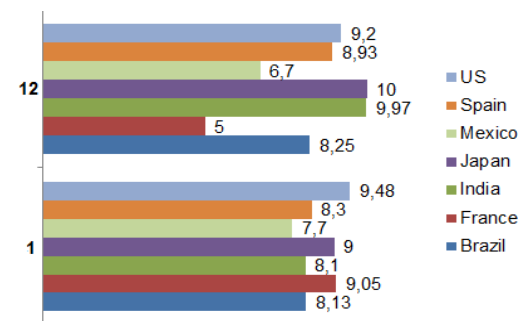


Figure 5: Results by country for Knowledge – Categories 1 and 12

documentation of the end user. In addition, for the category 5 the level of use is higher for HCI when compared with SE. This was expected since this category is normally used in HCI domain to validate user requirements and user interfaces.

## 6 RELATED WORK

For the best of our knowledge, no empirical study investigates the use of HCI approaches in the development of interactive systems following the CMMI-DEV. However we found three relevant studies that report the state of HCI, usability and User Experience practice in the industry [1, 8, 9].

Ardito et al. [1] performed an experimental study conducted in Italy with software companies to investigate the use of Human-centered design. The authors did not use a measure to investigate the level of knowledge about HCI, but they concluded that many software developers do not know well what usability is, and they know even less about UX.

Hussein et al. [8] performed an ethnographical study to understand how HCI is being incorporated in Malaysian enterprises. A high percentage of participants have never heard about HCI term (63.1%) neither about Interaction Design (57.1%). Even if 64.3% of the participants have heard of usability, 90.5% of them have never heard about usability standards of user interface.

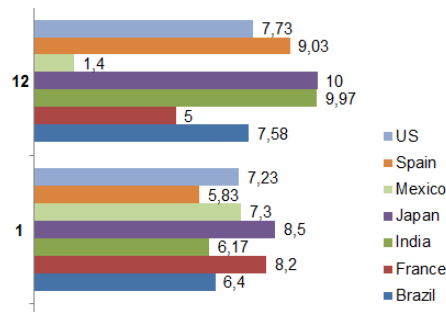
Ogunyemi et al. [9] performed an exploratory investigation in Nigerian companies; they found that seventeen organizations (77%) indicate to be aware of HCI and five organizations (23%) are not aware of HCI. Although 17 organizations claim to be aware of HCI, the responses about the HCI methods applied in these companies do not support this claim.

Our results show that the knowledge and use of HCI approaches is low compared with the central point (5) of our scale. The mean of eight out of fourteen HCI categories is less than 5 for the knowledge. It is the same for the use of HCI categories. The findings of the related studies corroborate with our findings. In other words, the software developers do not know and use enough all HCI approaches to apply in practice.

## 7 FINAL REMARKS

This paper presents the planning and the initial results of a study that aims to identify to what extent software developers that follow CMMI-DEV, a well disseminated model of software engineering best practices, know and use HCI approaches. According to our descriptive results, we conclude for now that the knowledge and the use of HCI approaches in the industry is not yet enough to develop useful and usable interactive systems.

We continue to perform recalls to obtain more results of our survey and then perform complete statistics analysis. Our next steps will be to focus this investigation in only few countries for a deeper study. Moreover, we intend to define guidelines of how perform each CMMI-DEV engineering practice considering HCI approaches.



**Figure 6: Results by country for Use – Categories 1 and 12**

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