Ranking of the Best Brazilian Universities and Professors in Information & Communication Technology: A Methodology for a R&D Lab of a Multinational Company in Brazilian Consumer Electronics' Industry

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Abstract--**The objective of this paper is to present the methodology used for identifying the best Brazilian universities and professors in research topics of Information and Communications Technologies (ICT) sector. This analysis was part of the R&D Lab planning activities in order to establish cooperative research projects with local universities. The motivation arises from the fact that Brazilian research environment is not enough mapped/studied, especially for applications related to the company's demands. The country has just started to provide competitive differentiation in R&D activities and most universities are more concerned with teaching/researching than working with Industry. The theoretical framework used is the innovation network management focused on the search for external partnership and the analysis of main universities ranking methodologies and bibliometrics indicators. Briefly, the methodology created can be separated into two phases: Identification of top universities; and identification of top professors and research areas on ICT. From 10 universities and 150 professors it was analyzed papers and thesis (Master/Doctorate) since 2009, summing up almost 4.000 documents. The result provided a Brazilian research map on ICT sector and it can be used to start establishing partnerships with universities.**

I. INTRODUCTION

Innovation plays an important role on the public and private agenda in almost every country. Recent studies of innovation such as Chesbrough [6] demonstrate that firms which are too much focused on internal innovative competencies may miss opportunities for not reaching external competencies. Many knowledge sources necessary to achieve innovation can only be found outside the firm. Modern innovation processes require firms to master specific knowledge about different users, technologies and markets, [15, 6] trough a non-linear, iterative and multi-agent innovation process [22, 30, 14] The university in this context is mentioned by Laursen and Salter [16] as the "engines of growth" and one of the main channels for generating and enabling future innovative ideas.

Having in mind that searching for external sources of knowledge is an important part of the innovation process this paper will present a methodology developed by a Research and Development (R&D) Lab of an Asiatic Multinational Corporation of the Consumer Electronics (CE) Industry installed in the Brazil since 2004 (the R&D Lab however was formally constituted in 2011, seven years of the beginning of operations). This methodology intended to map academic competencies and connect the R&D Lab to the researchers from Brazilian top universities on fields of Information and Communication Technology (ICT) and which are related to CE.

The R&D Lab subject of this paper was constituted not only for the traditional role of supporting local production, but also with the intention of creating interfaces with specialized institutions and creating innovation opportunities at a global level. Through this paper the term R&D Lab will be utilized to refer to the organization subject of this study. Its mission is to build local technological competence and self-identity in the context of all others R&D centers worldwide from the multinational company, aiming to become a reference in core technologies to the Headquarters' Research and Development lab (R&D HQ).

Since 2012 the R&D Lab was assigned to activities for carrying out basic and applied research on advanced technologies and then creating innovative offers which can then solidify the corporation position as a global leader. Brazil is recognized as an important player in areas such as petroleum, airspace and agriculture technology, especially regarding to biotechnology, and bank security. This last area is mostly fostered by private corporations whereas the first ones are mostly supported by public investments. Notwithstanding, these areas do not represent the largest research areas in Brazilian universities, and, furthermore, they are not fully aligned to the company research and products (consumer electronics). Under these circumstances, the question that guides this article arises: **how to search for technologies and potential partnerships without having any previous study about this specific research environment and competencies in Brazil?**

Looking to others R&D Labs of the company, it seemed clear that they already had mapped the main competencies of their universities, professors and research centers. However, in Brazil's context, as it was the first time this process was being executed and no previous study about it was found. It becomes clear that all data should be built from the scratch. Then, one of the first concrete actions in innovation management was to map local technology competences in the areas of Computer Science (CS) and Electrical-Electronic Engineering (EE) – areas most related to ICT sector – in the domain of the main Brazilian universities trough the methodology explained by this paper.

The main objective of such activities was to answer the question about what are the core competencies and the main research areas in Brazil that may support R&D activities globally. This was needed mainly because Brazilian private sector does not have a close connection with the university and a tradition of performing industrial research internally or

externally to the firm. The corporations which declared that had innovated [12, 3] in their products or process recently performed few interactions with the academy and had not submit almost any patents. Taking by example indicators regarding number of patents generated by Brazilian institutions or professionals, Brazil has filed 679 patens requests on United States Patent and Trademark Office (USPTO) in the year 2012 and had only 196 patents granted on such office, according to data organized and provided by Brazilian Ministry of Science, Technology and Innovation (MCT)[1].

Brito [3] remarks that the main origin of the Brazilian patents is not from firms but from the universities. Almost 59% of the patents filed at the Brazilian Patent Office, in the period 2001-2008 were requested by universities. On the other hand, the author reminds that in case of United States, for instance, the average of college and university patents is around 4.5%. All the others were requested by firms. Therefore, when talking about patents granted, one is talking about the ability of the company to create knowledge and incorporate them effectively to their products and processes.

Regarding scientific publication the scenario is more comfortable, even though it has innumerous room for improvement. It was accounted 55.803 Brazilian publications in 2012, number that represents 2.29% of world publication and 54.6% of Latin America publications, according to Web of Knowledge information displayed at MCT website. Using information available at SCIMago [2]website, in 2010 Brazilian has around 47.000 documents. Using information of MCT, the number is higher: in 2010 Brazil produced 140.000 documents, being 72.000 published in Brazil and 66.000 published abroad for the same year. Brazil is at the 15th position in publication ranking according to SCIMago since it had started to count publications reaching around 460 thousand documents. United States obviously is the first one with more than 7 million documents. The second country in Latin America is Mexico at 28th position with 166 thousand documents.

In addition to the quantity aspect, according to a study performed by Thomson Reuters [1] regarding the citation impact of publications from BRICS countries, the qualitative aspect is also relevant. The areas of Engineering, Physics, Mathematics and Computer Science are the ones which Brazilian publications have highest impact in the world. The first three subjects has an impact at least 0.8 higher than the world average citation impact. This indicates that there are interesting researches being performed in Brazil and a good amount of external knowledge sources available at universities.

These data above is important to provide a context about the Brazilian research environment and reinforce the relevance of this output in the methodology proposed. Perkmann and Walsh [22] reminds that most of the work regarding the collaboration between firms and universities prioritizes the study of the effects of the relationship, such as patents, publications and licensing. On an open innovation context more attention is needed on the roles played by both firm and university and on the relationship itself. Depending on the type of relationship, more knowledge can be exchanged and absorbed by the firm [7].

Another important remark by the same authors [22] is that most collaborative research in any country is partially supported by public funds, lowering the cost to firms of carrying R&D activities and for attracting international investments in R&D. Brazil, as well as many other countries, provides a set of mechanisms for supporting R&D activities especially trough tax incentives and grants [20]. Many of those incentives aims to motivate multinational companies creating factories and R&D centers in the country as long as the company brings forth benefits such as employment creation, improvement of the local workforce quality, increase of competition and technology transfer. The support for innovation and private R&D expenditure in Brazil has been increasing in the past fifteen years. It is justified by the strong correlation between spending on innovation, higher productivity and economic growth.

One of the main mechanisms for fostering private R&D activities is trough the Law commonly as "Informatics' Law" (Law nº 8.248/1991, modified by Laws nº 10.176/2000 and nº 11.077/2004) and it applies to corporations that produce informatics' goods on Brazil. It corresponds to around 65% of all public innovation expenditures on R&D activities. In a simple manner, it provides a mix of tax benefits/exemptions for enterprises which products informatics goods in Brazil, on the condition that enterprises invest 4% of revenues from domestic market on R&D activities. The R&D Lab subject of this paper is mainly sustained by Informatics' Law since its creation as any other R&D lab from ICT sector in Brazil.

In order to answer the question proposed, this paper is organized in six sections including this introduction. Section 2 will present the study methodology for preparing this paper. Section 3 will provide a brief description of the theoretical review used for developing the aforementioned methodology. It will discuss about strategic searching for external knowledge and the importance for systematically doing this. It will also present a similar case of study. Section 4 will provide more details regarding the roles played by the R&D Lab object of this study. Finally, section 5, the core of this paper, will explain all the steps taken for mapping Brazilian academic competencies in the areas of Computer Science and Electrical Engineering. The first part of section 5 will provide the steps for mapping researches of the top ten Brazilian Universities; and the second part will provide the steps for analyzing bibliographic indicators of main professors from those universities. The last section draws final considerations about the use of this methodology inside the R&D Lab and regarding the applicability in other knowledge areas, business

[1] Source: <http://www.mct.gov.br/index.php/content/view/350928.html>. Accessed on 2014, January 10th.
[2] Source: < http://www.scimagojr.com/countryrank.php>. Accessed on 2014, January 10th.

contexts and even other countries.

The methodology presented in this article intended to contribute with a proposal of a process for mapping and classifying Brazilian universities' research in order to find and connect experts to the industry. On the particular case of study the R&D Lab where the methodology was developed the interest was on research topics of ICT fields. Nevertheless, the methodology can be easily adapted to any knowledge/research area as the source of information gathered is the same. The only difference relies on the classification according knowledge area that will be, obviously, different.

II. RESEARCH METHODOLOGY

This section introduces the methodology and procedures for the development of this study. The work is structured in three main steps: i) bibliographic content survey; ii) observation and diagnosis of Brazilian R&D Lab context, especially regarding to legislation and to academic production/environment; iii) development of a methodology for mapping and classifying Brazilian universities' research.

The bibliographic survey presents and discusses the review of the existing literature which included: management and search for external sources of knowledge, relationship between Industry and Universities, and comparisons with similar methodologies (section 3).

The R&D Lab context observation and diagnosis regarding: the Lab strategy and context in Brazil, some legislation aspects for carrying research activities for ICT sector and scientific outputs from Brazilian researchers and universities; (section 4).

Development of a methodology for mapping Brazilian research, which consists on the definition of a new university ranking focused on Brazilian context and analysis of all scientific production from the past four years on areas related to the company strategy (section 5). By scientific production we understand as documents such as thesis, dissertations, papers and patents. All those outputs were analyzed and classified according to the knowledge areas, in three different levels, from a broader area to a specific one

This work consists on a descriptive research, which unit of analysis is clearly defined (Brazilian universities and researchers) and the goal settled was to gather accurate information about them, reasoned on the use of quantitative and qualitative variables, and eventually, on the relationship among those variables [27, 26]. The majority of data gathered for this work is available at Brazilian Ministry of Education and Ministry of Science, Technology and Innovation, as well as, at public universities' digital libraries (details at section 5 and 6). Some data is available at private bibliometrics databases.

It was author's option to first explain the study methodology as it may better guide the reader on a better comprehension of this paper as it contains specific information regarding Brazilian research environment and regarding the R&D Lab.

III. CONCEPTUAL BACKGROUND

In the firm innovation processes, the external knowledge plays an important role on the creation/incorporation of new knowledge and it avoids learning traps, i.e. the risk of an overreliance on internal knowledge [23]. According to Purcell and McGrath, sourcing and acquiring external knowledge is a primary concern of business organizations, which source this knowledge trough external search activity [23:158]. The search activity is part of the organizational learning process through which firms attempt to solve problems. It is posted as "an organization's problem-solving activities that involve the creation and recombination of technological ideas" [13:1184]. It is motivated in response to problems, such as, a need to improve upon current technologies [19].

Many companies had failed in recognizing and managing technology sourcing as a strategic business process [5] even though some of them explored many forms of business relationship with external technology sources. Procter & Gamble (P&G), on the other hand, is an example of a company that successfully modeled an approach to innovation. The method named "connect and develop" aims to connect with external sources of new ideas – including not only the universities but also government labs, suppliers and competitors – and then develop those ideas into new or refined products using internal teams or other external companies.

A relevant work regarding the search process is from Katila and Ahuja [13]. The authors had extents prior work which defined two mechanisms for search: local search, use of preexisting knowledge for address a problem (exploitation search) and distant search, to move away from current knowledge base (exploratory search).Authors claim that firm search effort cannot rely only on the scope of their search (defined as the degree of new knowledge that is explored) but also in the search depth, which is the degree to which existing knowledge is reused or revisited. In this way, this work asserts the idea that firms can be differentiated to the extent to which they explore new things and also to the extent to which they master the old ones. Following Schumpeter's classic work [25], exploitation combines existing solutions to generating new combinations as well as the exploratory search is able to provide new solutions.

Reference [15] extends this research but with a different approach: the external innovative search efforts rather than the impact of reusing internal existent knowledge. Laursen and Salter rely on the channels that firms use when searching for innovative opportunities, like suppliers, universities and end users. The attention then moves to the variety of channels used by the firm. The number of different search channels is named by the authors as external search breadth. External search depth refers to the extent to which firms depends on different external sources. Together, those concepts mean the

openness of a firm's external search process. According to them, searching for new ideas involves heavily absorption of knowledge from the external sources. Firms spend time and put effort to understand habits and routines of different external knowledge channels. It is a learning process, characterized by the trial and error and by the uncertainty about which innovative opportunity will be the most rewarding.

A different and complimentary view of this process is the work of Purcell and McGrath [23]. It is an effort to illustrate a framework of the external search process opposed to the 'classic' search process. The framework establishes at first the drivers or the motivation of the external search. In the case study, the motivation was to close knowledge or equipment gaps, but any other drivers can be added to the framework. Next, it should be defined the search type: problem-oriented, when a problem is well defined prior to the search action; solution-oriented, when problem is not well defined, there is a wider number of possibilities, across different areas of technological disciplines; and emergent search, when it happens at the individual level with no prior problem. The next step consists on the search action, which can be 'multifarious' (when different groups perform external search simultaneously in order to pursue different results/opinions about a very open problem) or singular (when the problem is better defined and the search is focused on one source of external knowledge, such as universities or research labs).

Furthermore, the main contribution of that paper relies on the search paths. According to the authors, the classic models of search, the activity was engaged in exploitative and exploratory search although externally focused. In their work, however, the social dimension is added to the technological trajectory of search. The search on social dimension may happen trough informal or formal search mechanisms, according existence or not of the consent/recognition of the firm for performing this activity. It was found on this work that most of search mechanisms carried out by the case study were trough informal mechanisms on the personal and professional networks of each search actors, providing access to both local and distant external knowledge sources. Next, the framework states about the selection of the possible sources of external knowledge (suppliers, personal and professional networks, subsidiary partners, universities, etc.). And finally, it states about the frequency of the search activity, where the authors claims it is an ongoing task, based on the results of their research.

Perkmann and Walsh discuss about the search and match process between universities and firms, instead of looking at the outputs of this relationship such as patents. Based on previous studies, the authors had consolidated different formats for a relationship between firms and universities occur, distinguishing them based on the levels of knowledge interaction between those two players. Authors claim that usually more than one format can be practiced simultaneously. On the Table 1, the interaction or "relational involvement" is higher from the top to the bottom.

Within the general context of 'open innovation' the first two formats of interaction are more interesting, as they facilitate the establishment and maintenance of a relationship over a longer period of time. The first one, research partnership, consists on a formal arrangement with the goal of co-operate on R&D activities, intending to generate high relevant academic results and supporting firm to solve open questions in some research area. The second one, research services, is "paid-for" services, performed by universities and oriented by firms. The outputs may be similar to the previous one but on this type of relationship firms already has a research question to deal with it. The other formats are less formal than the first ones and its output may be harder to absorb by the firm.

On this matter, Cohen and Levinthal [7] introduced the term "absorptive capacity" as the "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" [7:128]. The main message from this work is that firms cannot rely only on the search process if this knowledge is not assimilated or exploited by the corporation. For being able to create dynamics capabilities a firm needs to establish a set of organizational routines and process for incorporating such external knowledge. Perkmann and Walsh reinforce this aspect when they state a way for managing the relationship with firms-universities: first, a process of searching and matching knowledge and then a process for managing all

TABLE 1: UNIVERSITY–INDUSTRY LINKS

Research partnerships	Inter-organizational arrangements for pursuing collaborative R&D
Research services	Activities commissioned by industrial clients including contract research and consulting
Academic entrepreneurship	Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own
Human resource transfer	Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty
Informal interaction	Formation of social relationships and networks at conferences, etc.
Commercialization of property rights	Transfer of university-generated IP (such as patents) to firms, e.g. via licensing
Scientific publications	Use of codified scientific knowledge within industry

Source: Perkmann and Walsh [22]

those collaborations arrangements. The main focus of innovation management on this case changes from knowledge creation to knowledge trading and managing knowledge flows [28].

Given this theoretical literature review, a Brazilian similar case of study was identified. Quadros, Consoni, Quintão and Vieira [24:3] propose a similar methodology of the one that is described in this paper (see section 5). The authors on this work remarks that some studies "focus exclusively on the structural aspects of the firm, leaving aside the central issue regarding the strategic and managerial choices", reminding the work of Laursen and Salter [16] that affirms that the chance of success with university projects is also related to the strategic choices of innovation management activities, rather than size and age of the firm. The authors also distinguish between strategic searches from unaware search. The first one concerns about "strategic innovation objectives and requires a more pro-active management of the search" while the second one "is based on empirical and informal methods for accessing external partners" [24:3].

Then, reference [24] proposes a methodology for the identification, qualification and classification of capabilities of Brazilian research groups in technologies applicable to the automotive industry:

> *"Research Groups [RG] here refers to the organized unit of research involving one or more senior(s) scientist(s), their students, associate researchers and technicians. RG do not require necessarily an S&T [Science & Technology] certification, as the one the Brazilian CNPQ [National Counselor for Research] grants to groups registered in its directorate of research groups […] What makes a RG distinct is rather its capability to mobilize competencies and resources in a scale that raises substantially the productivity of research." [24:5]*

That means the unit of research is larger than our methodology, which looks to the professor/researcher as the research unit. On that research, it was found around 265 research groups actively working on the topics defined by the company. Several data were collected from the groups, especially trough an electronic questionnaire as not all information could be found on the internet and the groups were spread all over the country, the fifth largest in the world. The main point regarding such methodology is that the information gathered was not 100% accurate as only 47% of research groups had answered the questionnaire and not all research groups keep their information updated on the respective platform. This means that even though the information found is reliable and strategic to the firm some external knowledge sources could not be achieved. The methodology presented on our paper, by its turn, is based on official registers that are public provided by Coordination for the Improvement of Personnel in Higher Education (CAPES, acronym in Portuguese), a secretariat under the Ministry of Education, and it is complete in the sense that every research institution must keep their information updated on the Ministry.

On the next sections, before going through the explanation of the methodology of external knowledge search, a context regarding the Brazilian research environment and the roles played by the R&D Lab object of this study will be given.

IV. REGARDING THE R&D LAB

In the context of the last years firms have been facing growing challenges coming from fast technological shifts. Multinational corporations have increased their efforts to integrate their subsidiaries into research and development and innovation activities. Those corporations have increased the decentralization of innovation activities in such a way each subsidiary contributes to generate knowledge and innovation for the benefit of the corporation [4, 8].

Furthermore, multinational corporations' headquarters have been carefully analyzing the subsidiaries' capabilities in order to decide which one will receive more innovation responsibilities. At the same time, subsidiaries contribute to the process of decentralization of activities by seeking more complex responsibilities in order to assure their competitiveness and survival [9].

In this context, Brazilian subsidiary has an advantage among the others R&D labs: the indirect benefits from Informatics' Law. The obligatory investment of 4% of domestic market revenues in R&D activities provides enough budget to maintain most part of the R&D Lab. In this way, the Brazilian Lab does not need to compete for headquarters' investments, even though it needs to compete for innovative projects.

The R&D Lab in Brazil is part of a global R&D of a Multinational Corporation in the Consumer Electronic Industry. The company presented on this paper opened a factory in Brazil in 2004 and since then has performing R&D activities in the country, first with the creation of an external R&D company and then with the establishment of an internal R&D Lab in 2011. On this period both divisions had worked almost exclusively with experimental development activities and local adaptation of technologies for mobile devices, notebooks and printers, focused on local market and demands from the headquarter. As stated before, since 2012 the internal R&D lab, subject of this study, was assigned to activities of carrying out basic and applied research on advanced technologies and creating innovative offers that can solidify the corporation position as a global leader. The R&D Lab simultaneously proposes innovative projects as competes for global projects within the R&D Centers network and cooperates with those R&D centers in global projects where complementary competences are necessary and profitable.

Whereas development activities started on 2004, a mature organizational process was established and validated since then. On the other hand, the research group created on 2012 is still in early stage and the group is building everything from the scratch. Briefly, the main organizational roles for

this group are related to external competence searching and knowledge acquisition in core technologies, especially through partnerships with universities and others R&D labs. Those researches should end up on the construction of a prototype or a proof of concept, which later it should move to other departments responsible for the remaining stages of the production process whether relevant to the company.

Research demands may come from two sources: internal strategic projects, where the local R&D Lab defines what and how to carry a project; and by request, where the headquarter request project proposals for specific issues. On both scenarios it is imperative to have a consistent external knowledge network and a database compiled with such information. Thus, one of the first activities of this group was to gathering information about top universities, main professors and researchers of ICT area in Brazil. In parallel, an organizational process was defined in order to organize all activities from external to project execution and technology transfer. A high level overview of such process is showed at Fig. 1 Main stages of a research project.

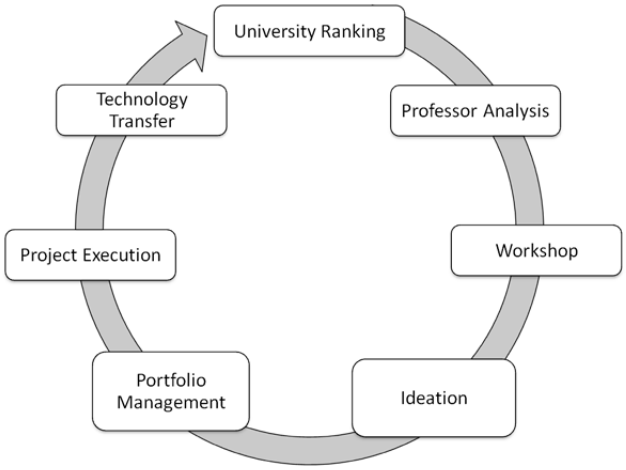

Fig. 1: Main stages of a research project
Source: Own elaboration based on R&D Lab specific information

Stages 1 and 2 will be explained on the next section and are related to the search of external knowledge. The next stage consists on scientific workshop with main professors of strategic research areas. On those workshops, professors had the opportunity to provide details about his/her research and propose partnerships projects. Then, after each workshop it is performed brainstorming meetings with internal research specialists, in order to generate and record ideas with potential to be converted in projects of innovative technological research (stage 4). On this stage, due to high number of ideas it was noticed the need to manage those ideas in a robust and concise manner and a specific process for portfolio management of ideas was established. On this process, every idea is evaluated according to strategic steering. As a result, there was a group of potential projects that should be evaluated and selected by stakeholders and sponsors. After selection, projects follow trough stages 5 and 6, self-explicable. The drivers and criteria' developed for this part of the process is described by Lenhari, Leite and Lizarraga and it will also be presented on PICMET Conference 2014 [17].

Given the context regarding Brazilian research environment and regarding R&D Lab particularities, the next sections will present the methodology for mapping and starting partnership in research projects with universities and professors of Information and Technology Communication in Brazil.

V. MAPPING RESEARCH COMPETENCIES IN BRAZIL

This section will present the methodology used for mapping out research competencies and capabilities of Brazilian universities, identifying researchers on topics related to CE and ICT in Brazil. The methodology consists essentially in two main activities. Both activities are being described in the next subsections: subsection 5.1 will discuss about the identification of the top Brazilian universities on research areas addressed to the company needs; and subsection 5.2 will bring forward the identification of core research areas and top professors from those universities.

A. Finding the Best Brazilian Universities

The first challenge for the team responsible for developing this methodology was to identify the best universities with graduation programs on computer science, computer engineering and electric engineering. To identify the best Brazilian universities, the first approach taken consisted on searching official statistic about research programs in Brazil. The main agency responsible for research and higher education in Brazil is CAPES, the Ministry of Education's Committee for Post-graduation Policies, created on 1951. CAPES has played a key role in expanding and consolidating graduate programs in all states of the Brazil. One of the main assignments of CAPES is the evaluation of graduate programs. "CAPES grade", as it is named, it is a consolidated and official statistics of every single university regarding their graduate outputs. It can be considered as a type of graduate program ranking as it gives grades that vary from 3 to 7 to every program, even though it was not designed to be a ranking. Its main goal is to evaluate and disseminate Brazilian scientific results.

After, a second approach consisted on consulting an international university ranking such as Times Higher Education, QS, SCImago and Webometrics. In the past years, universities rankings had increased in quantity and in importance, influencing the way the universities around the world understand productivity and quality.

Ranking, as defined by Glänzel and Debackere [10], is positioning comparable objects on an ordinal scale based on an order relation among functions or scores associated with those objects. These functions are called indicators. Different indicators representing different aspects of quality form the components of a composite indicator, the basis of the

ranking. Composite measures are used when single indicators cannot adequately capture multidimensional concepts.

This method has been used on several university rankings but the authors [10] warn about problems that may arise when applying composite indicators: possible interdependence of components, changing weights can result into different ranking, and reduction of the multi-dimensional space to linearity. Besides those methodological issues there are also others that may come from the data itself or the way to collect it. For example, results from a measure may be obscure (hard to determine all the research process) and not reproducible (data may be not available or may change over time). Other measuring issues concerns about: the reliability of the data used, different bibliographic output documents analyzed (conference papers, journal papers, magazine articles, notes, reviews, patents, etc.), different habits for paper citations (subject-specific) and different journal impact factor on different areas of knowledge, and different demands and inputs for each University [2, 10].

The first university ranking to evaluate research activity was the Academic Ranking of World Universities (ARWU) as known as "Shanghai Ranking", published in 2003. Since then, some other institutions (not necessary related to Research/Education business) created other rankings, using their own methodology. Those rankings and their methodologies were deeply analyzed and then it was noted they were also not enough to identify all top universities in Brazil, or even in Latin America.

They present some issues when analyzing research Latin-American environment: *i)* it does not take in consideration regional strengths, needs and relevance of researching local subjects; *ii)* it does not contain a relevant number of Brazilian Universities; *iii)* it usually does not distinguish between courses from engineering, medicine and/or social studies; *iv)* bibliometrics data can contribute to evaluate some of the research aspects, but it is necessary to normalize and standardize these measures. It is still not possible to compare different profiles/courses; *v)* some of those rankings take in consideration international awards, such as Nobel Prizes (as Times Higher Education Ranking and "Shangai" Ranking - ARWU), that may not be used to select best scientists in Latin-America as the region had not received so many awards. Actually, it is noteworthy there are a small number of scientists who won Nobel Prizes in Latin America and none of them are from Brazil. Latin Americans scientists won only 3% of all Nobel Prizes, and only 1% pertain to research areas such medicine or chemistry (the other 2% were given to literature or peace[3]; and *vi)* mainly, these ranking does not cover all studies performed in Portuguese, which are by consequence not cited and has a small impact abroad. This also happens with "not English-journals", neglecting academic work published in countries with different languages [29, 21].

In summary, it was noticed that universities environment is more complex than described in those rankings. Rankings can provide useful information that may support decision of investment by the firm on a cooperative research project within universities. But, on the other hand, it became clear the necessity to perform a more detailed and more complex analysis in order to reflect important characteristics of the performance of each university.

In order to handle all these issues, it was created a new ranking by merging relevant information from all these international rankings plus the Brazilian official evaluation of graduate programs (CAPES). A total of ten different universities rankings were considered and for each one were given different weights, according to their methodology: based on bibliometrics indicators, based on surveys, based on the relevance/opening in the web (cybermetrics). The list is available at Table 2.

This classification was created by the internal group of the R&D Lab as a way of organizing the information about those institutions and following classification of Laursen and Salter [15]. The highest weight was given to CAPES grade due to the quality and reliability of its information, and also due to the fact that every single graduate course in Brazil must report to CAPES. By merging the results of Brazilian universities on each ranking, the group had created an internal top Brazilian university with about 40 research universities. Having this list, the internal R&D Lab group selected the top 10 and then moved to the next step, which consisted in the analysis and understanding of their main research areas on Computer Science and Electric Engineering.

TABLE 2: UNIVERSITY RANKING INSTITUTIONS USED FOR IDENTIFY TOP BRAZILIAN RANKING

Method	Ranking Institution
Survey	Times Higher Education (THE)
	QS
	Ranking Universtário da Folha (RUF) – Brazil
Bibliometrics	"Shangai Ranking" (ARWU)
	SCIMAGO
	Leiden University Ranking
	University Ranking by Academic Performance (URAP)
Cybermetrics	Webometrics
Other	CAPES

Source: Own elaboration

For doing that, it was collected all Master dissertations and PhD thesis from the past four years of each of the top ten universities in these two disciplines. All information is provided by CAPES and/or by each University. Afterwards, all those documents (around two thousand documents) were classified according to the knowledge areas, in two or three levels. For instance, a thesis about 4K TVs would be classified as Signal Processing (first level), Imaging/Video Processing (second level) and Video Coding (third level). In the same way, a thesis about data mining would be classified as Artificial Intelligence (first level) and Data Mining (second level). A peer review process for the classification was also

[3] Source: <http://www.nobelprize.org/>. Accessed on 2014, January 10th.

performed.

Finally, it was possible to take a snapshot of the main topics that researchers are working on. At this point, the analysis was focused only on quantitative data and did not take in consideration the qualitative aspect of each research. Based on this big picture, it was possible to select professors who currently works in fields related to R&D Lab strategy or at least exclude the ones who are not attached to it. With this list of professors, the next step would gather deeply information about them.

B. Building A Database Of External Knowledge Sources

This list of around 150 researchers was used as an input to the next activity, which consisted on the identification of strong technologies from these institutions. To accomplish this task, it was collected all publications, patents and bibliometrics information of the selected professors.

An overview of this process can be seen at Fig. 2.

In a similar manner of previous analysis of thesis/dissertations, all papers from the past four years of the list of researchers were collected and classified according to the knowledge areas. For performing this task it was used "Lattes Curriculum", the Brazilian online platform that enables researchers to store information about their papers, research groups, thesis advisory, participation in conferences, patents and several other information about research activities. It is informally known as the "LinkedIn" for Brazilian researchers and contains very reliable and detailed information about professors output. Some universities use this input for validate its metrics before sending the information to CAPES evaluation.

This platform was developed by the National Counselor of the Scientific and Technologic Development (CNPQ, acronym in Portuguese), another important agency for Science & Technology policy in Brazil, founded on the same year of CAPES (1951). The main focus nowadays of CNPQ is to provide fellowships to students from undergraduate to post-doctoral level, supporting the quality of Brazilian students. Nevertheless, this tool is a centre piece of this part of the methodology.

In addition to it, it was also gathered the information about the journals where those papers were published. It was collected information about Journal Citation Impact (JCR, provided by Web of Knowledge/Elsevier), Eigen Factor and a Brazilian Journal classification, named Qualis, also provided by CAPES. Qualis is a quantitative analysis (journal impact) of main scientific journals, including the Brazilian ones, according to their areas and relevance. All those data were combined and normalized in order to generate a ranking of the best journals where those Brazilian researchers had published ("Papers Ranking" in the Fig. 2).

Next, bibliometrics information was also gathered. It was consulted databases such as Web of Knowledge, Scopus and Google Scholar and from them, it was collected the following information: H-Index[4], i10-Index[5], amount of citations, number of publications (including conference proceedings), number of co-authors and others parameters. All these data were also analyzed, normalized and combined, generating a type of professor's bibliometric ranking.

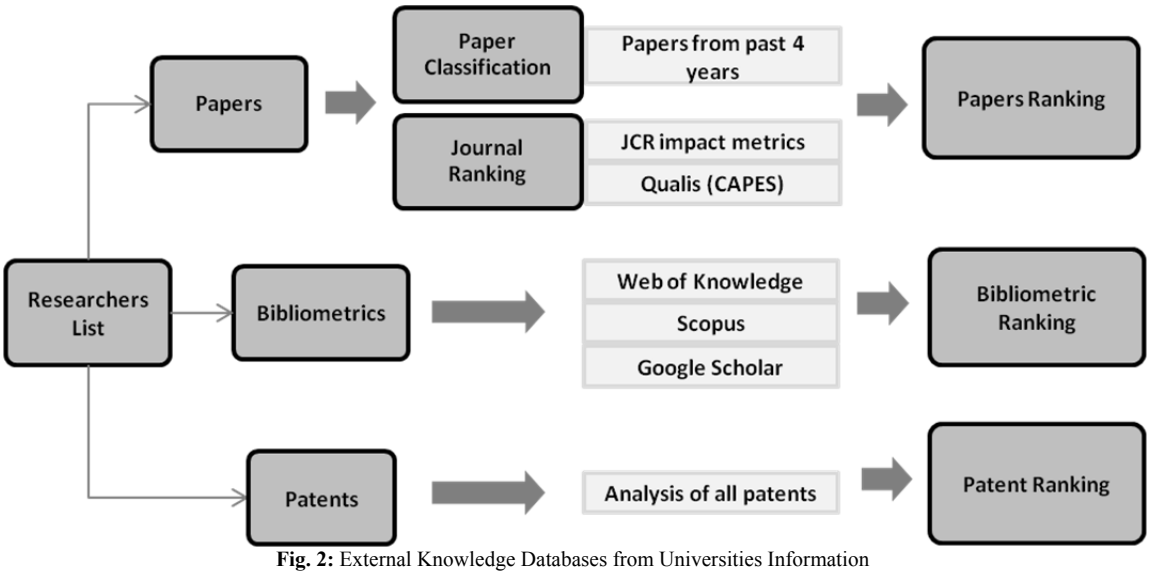

Fig. 2: External Knowledge Databases from Universities Information

Source: Own Elaboration

[4] The h-index attempts to measure both productivity and impact of the published. In other words, a scholar with an index of *h* has published *h* papers each of which has been cited in other papers at least *h* times.

[5] The i10-index indicates the number of academic publications an author has written that have at least ten citations from others. It was introduced in July 2011 by Google as part of their work on Google Scholar.

Finally, information about patents were collected and classified according to their areas/fields of application. All data was got from the Brazilian patent office, named INPI, and also form the American and European offices, USPTO and EPO, respectively. As mentioned before, Brazil does not have a large amount of patents. Within the information gathered it was not possible to build a patent rank as only one third of the professors list has at least one granted patent.

Putting all those quantitative information together (bibliometrics ranking, journals ranking, paper classification and patents) with the qualitative information about the research areas of each paper/research, the R&D Lab could identify the core competences and top professors of Brazilian Universities on the firm's strategic knowledge areas. The database built contains rich information about this entire context and different snapshots from it can be taken. This database is only the first step to start a partnership project with a university as it provides just a recommendation of the main researchers from the point of view of bibliometric information and academic reputation. When visiting these universities and researchers other aspects were added to the quantitative data, such as the propensity for the professor to work with a company – many professors in Brazil are not used or do not want to do it – and interpersonal characteristics. In addition, other researchers that were not previously mapped for some reason could be then added to the database.

Returning to the process described in the Fig. 1, after creating this database, visiting the suggested researchers and being introduced to new ones, the R&D Lab invited some of these researchers to a scientific workshop, where they were able to provide details about their researches and proposes new researches for cooperative projects with the R&D Lab. This activity ends the cycle of external knowledge source searching, initiating the cycle for portfolio management and project execution.

The result of the implementation of this study is a database with quantitative and qualitative information of professors from Brazilian universities whose research has positive impacts on the academy local and worldwide. By enabling R&D managers and directors looking for research topics and potential partners, this tool/database foster and support innovative projects at the R&D Lab in collaboration with top universities as requested by the headquarters and defined by the local R&D strategy plan. Moreover, it is oriented towards technologies which are considered strategic for the corporation's innovation purposes.

Regarding Perkmann and Walsh [22] consolidation of possible channels for establishing a partnership between a firm and a university, this tool provides substantial and straight information for almost all types This database is used mainly for planning and executing research collaboration projects and identification of researchers who can work as a consultant for a research internal project. But it is not limited to it, as it is used for: hiring top students/researchers, as it analyzes thesis/dissertations of students recently graduated, for identifying newly academic entrepreneurs and startups companies as several information about his/hers research projects are available on Lattes platform, and also for accessing the most recent papers just after researcher announces a publication on the same platform. In addition, the database is updated periodically every six months and at any time a relevant professor or a paper is found.

VI. FINAL CONSIDERATIONS

This paper presented the methodology developed by a subsidiary of a R&D Lab of an Asiatic Multinational Corporation addressing an important topic of innovation management process: the search for external knowledge source. This methodology can be used in two ways: prospecting new projects and research partnerships on strategic knowledge areas defined by the R&D Lab and/or selecting the most appropriated university/researcher for attending a specific request for proposal, generally demanded by the R&D Lab headquarter. In this way, it can be perceived as a tool for external searching process, focused on research, having the university as the main source of external knowledge.

Brazilian research environment is not enough mapped/studied especially for applications related to the R&D Lab products. Such environment also presents some obstacles, especially regarding to the very low rate of industrial research and patents. Notwithstanding, it builds valuable information of technological research competencies and top professors/researchers in Brazilian universities. In this way, the database is very valuable and strategic to the R&D Lab.

The importance of this work relies in providing a mechanism to find the most advanced technology research in Brazilian universities, in order to connect this with the Industry. The scope and methods used when collecting and analyzing information can identify technological opportunities at the very beginning. The information gathered and analyzed on this methodology is easily available but it is spread in different documents, websites and databases, so its merit is on consolidating it on a database and keeping it updated.

The methodology described here may support others R&D labs on the activity of searching for external knowledge sources in Brazil or in other countries with similar characteristics. Even though it is tied to industrial research demands, the steps taken to achieve this result can be reproduced and transferred to other knowledge areas, such as Biology or Chemistry as the source of data used should be similar for other areas. Moreover, not only firms can be benefited from it, but also universities can make it useful by better identifying all researches performed by it.

This work supports and influences the strategic definition of R&D projects/objectives. It is a useful tool for identifying and connecting university experts to firms, trough a database of experts and topics researched on those universities. It

makes the external search process easier and manageable, as well as the execution of R&D collaboration projects.

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