Computing and Higher Education in Peru

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Abstract: In Peru, the computing discipline as an academic field has been neglected during decades deriving in a low-quality higher education system and consequently shaping an academic community with modest participation within scientific production around the world. At the undergraduate level, universities have not adopted international standards or curricula recommendations that could contribute to improve the quality of computing and related engineering programs. Considering this context, the present document aims to present an overview of the current situation followed by suggestions toward the empowering of the field following international well-adopted practices and respecting local characteristics.

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1. INTRODUCTION

Computing has been strongly influencing the progress of mankind helping science, engineering and the business world make substantial advances. This trend along with its wide and pervasive presence in today's society makes computing a strategic discipline for the development of a country.

Computing degree programs have been shaped by cultural and technological trends reflecting different scenarios in each country/region as a product of local characteristics. However, there have been significant efforts to create international curricula recommendations and other materials. This leads to the challenging need of proposals capable of follow international references and respect local history and context.

In Peru, engineering and technology undergraduate programs have a history of attracting some of the best high school graduates. Higher education in computing programs is not an exception, but in contradiction is currently failing in preparing those students to be world-class professionals. Peru, at this moment, requires to take the route toward the education of a massive and skilled computing work-force that can actively contribute to the development and competitiveness of the country. In order to achieve this goal, higher education within the computing discipline should consider well-adopted international references.

Currently in Peru, computing-related degree programs have been given a diversity of names, however, that is not the major problem, but the lack of coherency when designing curricula for those programs. For illustrating the negative impacts of this situation consider that it is possible to take two degree programs with identical names and find that they produce graduates with very different background and performance capabilities. For instance, while some "Informatics" degree programs are oriented toward information systems, other "Informatics" programs are strictly based on computer science. Moreover, most computing-related undergraduate programs are named "Systems Engineering", creating local misunderstandings about the nature of computing in the academic community, the job market and high-school graduates applying to universities.

This article is motivated by the need of a better organization of computing careers in Peru. It contributes a set of guidelines for appropriately naming computing-related degree programs, and high-level definitions of the performance capabilities expected from their respective graduates. The recommendations are proposed under well-known international references and the local context.

The current context in Peruvian universities and local industry is described in Section 2, then Section 3 reviews the available international references for higher education and computing curricula. Section 4 shows a proposal for organizing undergraduate programs, and finally Section 5 is devoted to overall conclusions and ideas for future work.

2. NATIONWIDE CONTEXT

In Peru, the lack of regulation and the absence of investment in the computing field have been responsible for the spread of a distorted interpretation of the nature of computing. From an academic perspective, the major impacts are at the undergraduate level, where the country faces a wide diversity of denominations for the programs as well as curricula focusing the use of computing applications rather than their fundamentals. A survey conducted by the authors on 69 public and private universities yielded the following denominations: 30 Systems Engineering, 8 Systems and Informatics Engineering, 8 Informatics and Systems Engineering, 7 Informatics Engineering, 3 Computer and Systems Engineering, 3 Systems and Computer Engineering, 2 Software Engineering, and 4 with different names. Clearly the predominant denomination is *Systems Engineering*, often bundled with other names. The use of this title is also common in other South American countries (Ecuador, Colombia, Bolivia and Venezuela).

According to INCOSE (*International Council on Systems Engineering*)[1], the nature of *Systems Engineering* can be described as: "an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholders needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle." Therefore, *Systems Engineering* is defined with a different emphasis and body of knowledge than traditional publications describing the computing discipline. In general the field is improperly associated with *Systems Engineering*, which itself represents a different field of study.

Despite the fact that the Computing field has shown an increasing intersection with other fields of study, the concerns in Peruvian education arise from the incoherent design of undergraduate programs in most universities. Programs titled *Systems Engineering* are built upon computer science concepts at early semesters with a later focus on information systems and/or software engineering. Frequent courses are: algorithms, data structures, programming languages, computer networks, databases, operating systems, computer graphics, compilers, artificial intelligence, object-orientation, computer architecture, among others. It can be claimed that Peruvian *Systems Engineering* programs do not hold INCOSE recommendations, they are instead computing programs.

Given this context, the nomenclature being used in Peru is to a certain extent a distortion of international consensus around computing degree programs. This distortion imposes negative consequences to both computing professionals and real System Engineers. On the other hand, it makes difficult the enrollment of Peruvian students in graduate schools and jobs around the world. It is necessary to point out that this nomenclature has been used since the establishing of the first of these degree programs in Peruvian universities. It is not our intention to object the reasons behind that choice, but establish that its continuity is not convenient.

In addition to the diverse nomenclature and the lack of references for curricula design, there are other indicators that support the need for a re-organization of the computing field in Peru, some of which are listed below:

1. there are no doctoral programs emphasizing computer science;
2. there are no master programs where the students are involved in full-time research, working under the supervision of doctors in the field;
3. the country is not producing/exporting software in expressive quantities;
4. the scientific production in 1996-2006 was only 34 papers, according to the *SCImago Journal & Country Rank2*, averaging 3 papers/year;
5. most degree programs focus on the application of computing technology instead of the principles that enable its creation.

Considering these indicators it is observed that higher education in computing is not yielding high quality human resources as well as universities are not producing research papers. In fact, the lack of identity for the computing discipline distorted by the *Systems Engineering* influence contributes to reinforce the current scenario.

The impacts also reach the industrial sector. According to a diagnostic of the Peruvian software industry published in 2004[3], Peruvian software exportations reached only 7.3 million dollars in 2003, and despite an expected increase, it explicitly states the need for "the formation of more specialized professionals, according to the tendencies of international demand." The local industry demands world class professionals for being able to compete in the global market.

3. NATURE OF COMPUTING AND TERMINOLOGY

In a general way, several countries at some time have shared similar contexts in computing higher education, basically, a big spectrum of study plans at universities and significant differences regarding the orientation the plans are conceived with. One must consider that the computing field is still at its infancy when compared with other well established sciences, nevertheless, joint efforts have been spawned to create references and recommendations for curricula design and thus insert some coherence and common contents in this diversity of study plans. Major sample publications with guidelines are:

- *ICF2000 - Informatics Curriculum Framework*

[1] http://www.incose.org

[2] http://www.scimagojr.com

[3] http://www.apesoft.com.pe

2000, published by IFIP[4];

- *CC2005 - Computing Curricula 2005*, published by ACM, AIS and IEEE-CS[5].

ICF2000 has a generic view, so it is not a model curriculum but instead offers a global scheme for the demand of different categories of professionals interacting with informatics [4].

On the other hand, the latest computing curricula overview was published in 2005, resulting from the cooperation between ACM, AIS and IEEE-CS, where a core set of contents is defined for the following undergraduate programs: Computer Science, Computer Engineering, Software Engineering, Information Systems, and Information Technology. These profiles were built from specific bodies of knowledge in the computing discipline. The interesting contribution of this work is the differentiation among computing professionals.

One of the side-effects of such proposals is the high degree of freedom for the terminology used when referring to the computing field. In Peru, with Spanish as official language, translation must be conducted cautiously in order to preserve the nature of concepts. One of the major questions is related to the denomination of the field. Should we say *Informatics*, *Computing* or *Computer Science*? What is the correct name for the field?

Informatics (from the French word *informatique*) has its roots in the European Academy and is a term widely used by IFIP. This word inspired similar words in other languages, like the German *informatik* and the Spanish *informática*. In the US, *Informatics Inc.* was the name of a company that operated between 1962 and 1985, and possessing legal rights on the term prevented its massive use in that country [1]. *Computing* is the term currently used in the US. In [2], computing is defined as "the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all of computing is: What can be (efficiently) automated?" During a long time in the US, *computer science* has been used to refer to the entire field. Currently *computing* is considered a more adequate term, with *computer science* being a subset of it [3]. Due to this tradition and historical context it is however common that the French word *informatique* still gets translated to English as *computer science*. Moreover, nowadays the terms *Information Technology* (IT) and/or *Information and Communication Technologies* (ICT) are widely used as well. IT/ICT possess a more application oriented connotation and it is the industry's preferred denomination. In a wide sense they might be considered as synonyms of computing.

For the Peruvian context the words *informática* and *computación* can be used to refer to the same field. In general, *informática* is associated with applications of computing technology and *computación* as the major denomination of the field for academic purposes.

4. PROPOSAL FOR PERU

Peruvian universities are considered critical for the development of the country. In order to achieve high quality education, international references should be considered when designing new computing programs or re-structuring their current programs. However, a proposal of curriculum guidelines for Peruvian universities can not neglect their historical and cultural facts, thus, the authors do not recommend the adoption of CC2005 and/or IFC2000 guidelines exactly as they are. This proposal is intended to help local universities in defining more focused and coherent computing programs.

After reviewing the existing related bibliography and witnessing the experience of other countries (the authors were educated in Brazil, US, and Spain), it sounds coherent to follow some of the Computing Curricula guidelines. This model is widely used worldwide, both by emergent and developed countries. Certainly, it is necessary to adapt the guidelines to the local reality, as the model itself recommends, and the present proposal is framed in such context.

In this proposal we consider that the country requires three groups of professionals within the computing discipline:

1. Those who are committed to the scientific and technological development of computing. These human resources must possess a solid scientific and technological formation so they can contribute, through further research activities (in master and doctoral levels), to the scientific development of computing itself. On the other hand, they must also be prepared to apply their knowledge to the technological development through innovation in the industrial/commercial sector. It is recommendable to encourage this type of professionals to enroll in master and doctorate programs, and also attract them to teaching and research positions in the industry and academic institutions;
2. Those who use computing for the benefit of the organizations (public administration, hospitals, big businesses, banks, airports, and so on). These professionals should have a formation in computing but also knowledge about administration, economy, project management, and organizational issues;
3. Finally, for the immediate needs of the market, it is possible to educate professionals at a technician level, with specific capabilities in the use of computing tools. It is not the mission of the university system to produce this type of professionals, but of the institutions of short-term

[4] http://www.ifip.or.at/
[5] http://www.acm.org/education/curricula.html

technical education, many of which already exist in the country.

Considering the previous guidelines, it is proposed to implement in Peru the following four professional profiles, the first three as bachelor degree programs at universities, and the fourth as a technical career at institutions of technical education:

- *Ciencia de la Computación*: Based on the *Computer Science* profile of the Computing Curricula. These professionals correspond to the first type described previously and their preparation, which spans from theory to programming, must allow them to: 1) Devise new ways to use computers; 2) Develop effective ways to solve computing problems; and 3) Develop specific-purpose software and take on challenging programming jobs;
- *Ingeniería de Computación*: Based on the *Computer Engineering* profile of the Computing Curricula. These professionals also correspond to the first type described previously and their formation concentrates on the design and construction of computing systems that involves software and hardware, with special emphasis in new tendencies like embedded systems and industrial automation, orienting themselves to the study of hardware and its interaction with software and communication devices;
- *Ingeniería Informática*: Based on *Information Systems, Information Technology,* and *Software Engineering* of the Computing Curricula. The formation of these professionals, which correspond to the second group described previously, must allow them basically to: 1) Design and develop Software for organizations; 2) Integrate IT solutions and business processes to meet the information needs of organizations; and 3) Plan and manage the technological infrastructure of organizations. The word *ingeniería* is justified due to the engineering profile of this professional, dedicated to conceive and build solutions for organizations. The word *informática* express that this professional, more than developing computing itself, uses it as a means to attain her goals;
- *Carrera Técnica en Informática*: To produce "*informatics technicians*" capable to attend emerging needs of the market. They may hold a generic name bundled with specific titles according to their specialties (computer networks, web development, multimedia, etc). This profile corresponds to the fourth group described previously.

The *Software Engineering* profile proposed in the Computing Curricula is not considered as a separate degree program by the present proposal. Our understanding is that each of the three proposed professionals with university-level education require different levels of knowledge in Software Engineering. Therefore, the idea is to distribute the contents belonging to Software Engineering among the curriculum guidelines of the three proposed programs, according to the specific needs of each one. Evidently, the proposed *Ingeniería Informática* ought to have a larger emphasis in Software Engineering.

Our proposal for *Ingeniería Informática* includes knowledge in software and hardware, but do not emphasize them "for themselves," it rather uses them as critical instruments to achieve the major goal of satisfying organizational or industrial needs. It is also necessary to notice that Computing Curricula profiles as information systems or information technology do not have the word *engineering* attached to them, nevertheless, in the present proposal, *Ingeniería Informática* aims to graduate engineers capable to design and develop software solutions making use of a broad extent of Software Engineering concepts, justifying the *engineering* term.

Regarding the existing professionals, we also propose the implementation of master degree programs with an academic profile in software engineering, with full-time dedication for professors and students. The goal of such programs should be to provide existing professionals with quality knowledge and training that contribute in the short-term to increment the quality of Peruvian software. At the same time, we propose the implementation of full-time Doctoral programs in Computer Science in order to provide high quality human resources for improving teaching and research activities inside national universities and research centers.

5. CONCLUSIONS

Certainly, further discussion and debate must still occur to reach a consensus and establish the re-organization guidelines required by the computing discipline in Peru. The main goal of this paper is to highlight the current concerns and submit an initial proposal for discussion. The reader should recall that the *Systems Engineering* influence on computing programs also exists in another Latin American countries. We believe that the success of computing higher education in Peru depends on the use of international references and the independence of *Systems Engineering* influence.

As future work, there is need for a more elaborated document containing a detailed curricular and pedagogical explanation of the proposed profiles.

The re-organization of the computing field in Peru is a new challenge for the academic community and those representing the government and should be considered critical for helping the country to increment its participation in the global economy.

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