Variations in Computing Science's Disciplinary Diversity ²

The case of curricula recommendations

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Abstract: This article graphically explores the historical development of Informatics using the trajectory of curricula recommendations in Computing Science. Faced with the disciplinary diversity found in ACM computing curricula recommendations and related documents, the usual description of Informatics as an ever expanding field is challenged. Indeed, in the first period the disciplinary diversity fostered by the community was reduced. This reduction of diversity was accompanied by an increase in the depth of a few branches, structuring Informatics in areas such as Computer Engineering, Computing Science, and Information Systems. Since then, Informatics' footprint has increased, demanding a renewal of its disciplinary structure, which triggered the emergence of new related occupations. The graphic representations proposed here motivate a discussion of current professional tendencies, illustrating that Informatics history is richer than it is usually seen.

Key words: Computers and Education, History of Informatics, Disciplinary Diversity, Curricula Recommendations

1. INTRODUCTION

A set of disciplinary events and transformations has taken place across Informatics' lifespan. As Informatics' areas of expertise developed and its

² This article is partially based on Merkle [7, Chapter 1].

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niches were explored, they not only matured, but also established a corresponding division of labour. Throughout the process, unexplored gaps, abandoned niches, and reinforced barriers enabled the emergence, the maintenance, and the decay of disciplinary practices, old and new. It is usual to describe Informatics' related disciplines, such as the ones focusing on computing and information systems, as being in a rapid and constant expansion, as having an identity grounded on constant innovation, and as being the foundations for an envisioned social revolution.

Nevertheless, it has not been critically questioned how the disciplinary profile fostered throughout its development has varied; at least by most of those who work in Informatics. It is unquestionable that Informatics' consolidation can be associated with the great depth that its communities have developed within certain subjects. In terms of disciplinary breadth, however, over-specialization is a drawback, considering the demand for professionals who can work and communicate effectively.

Indeed, the widespread assumption that Informatics is an ever-expanding field does not correspond to the actual disciplinary variations found across its historical development. During Informatics' inception phase (until the 1960s), it had a higher disciplinary diversity than it was able to maintain during the seventies and eighties. During that first period, areas such as Anthropology, Linguistics, Design, Human Factors, Psychology, Industrial Engineering, and others were mentioned as contributing to the field. From that initial diversity, only some branches have been consolidated within the community, in fields such as Computer Engineering, Computing Science, and Information Systems. The rest became dormant, remained on the outskirts of particular disciplinary branches, or developed elsewhere. Information Science is an example of the latter.

Throughout this historical process of consolidation, the involved communities raised many barriers and bridges that ended up structuring Informatics as it is known today. Computer Engineering, Computing Science and Information Systems developed narrow but complementary constellations of interests focused on hardware, software, and systems, respectively. Interests in cybernetics, systemic approaches, linguistics, and anthropology have been slowly left out of the core issues of the profession. This decrease in diversity and increase in focus may have been appropriate in the past, but it is under revision now. Awareness of these dynamics can help the reorganization of Informatics as a whole, including a better understanding and appraisal of the roles that some recently emerged fields can play.

As traditional disciplinary branches became too insular, or as the cultural role of Informatics in society grew beyond its niche of expertise, theories and practices started to become insufficient to account for the richness of its

consequences. Given the opportunity, other branches emerged, such as Software Engineering and Human-Computer Interaction, increasing the established disciplinary diversity. Currently, the field is in a transition period and no disciplinary dynamics have stabilized yet. The introduced novelty has been challenging professionals, educators, law and policy makers, and politicians, who have neither grounds nor background to decide in which direction to go, or in what or whom to invest.

2. HISTORICAL DEVELOPMENT OF INFORMATICS

Figure 1 gives a synoptic view of the curricula recommendations and related documents published mainly in the United States. The graphic organization of the diagram is in accordance with the Unified Classification Scheme for Informatics, developed by Mulder and van Weert [8], cited in Mulder and van Weert [9, pp109-111], but it was not based on it.

It took a long time for Informatics to be recognized in the academic milieu. Although the criticisms were many, it continued to develop. As it developed, their social implications and consequences increased, but the disciplinary diversity of Informatics as a whole decreased. In terms of disciplinary relations, the consolidation of a field is concomitant with the construction of its identity and subject matter. Therefore, there is a tendency to narrow the kind of phenomena that a field encompasses during its inception.

For example, in 1954, a few years after the Association for Computing Machinery (ACM) was founded, its president, Samuel B. Williams, explained that the ACM was going to focus on what later became known as software and systems and their use, withdrawing hardware to engineering [14, p3]. This illustrates a historical watershed between two periods: a first period in which the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the then recently formed Association for Computing Machinery were organizing joint conferences, for example; and a second period in which the communities started to narrow down their interests in order to deepen their foundations. Through this process, the fields of Computer Engineering, Computing Science, and Information Systems slowly emerged, and became recognized across academia, industry, commerce, government, and other cultural venues.

Figure 1. Curricula recommendations in engineering, science, and business

Throughout the consolidation process, most of these fields in Informatics slowly withdrew human and organizational issues from their subject matters, developing perspectives restricted to the artefact, as if it were isolated from its context. In some cases, these issues remained in the domain of particular areas. For example, individuals or groups who were interested in people in Computing Science and in cognition/behavior ended up accommodating their interests in areas such as computer graphics, artificial intelligence, and project management. In Information Systems, the segmentation structured the field into Information Systems and Information Systems Management. Library and Information Science remained outside Informatics as an “application” area, and subdivided into Information Science and Library Science. With time, as the names indicate, each branch negotiated its disciplinary domain and its corresponding organization. Figure 1 does not depict this human dimension, which can be said to be orthogonal to its focus.

Reference to another disciplinary boundary was defended around thirteen years later. In 1967, Newell, Perlis, and Simon wrote a letter to Science, defending the field of Computer Science, explaining its differences, and discussing criticisms. In their definition “*Computer science is the study of the phenomena surrounding computers. ‘Computers plus algorithms, ‘living computers,’ or simply computers all come to the same thing - the same phenomena*” [10, 1967, p 1373, added italics]. In terms of disciplinary scope, their definition was narrower than earlier ones. One year later, a more restricted scope can be identified in another definition. In Curriculum 68, a subsequent set of curricula recommendations from the ACM, the committee grouped three major subdivisions that encompassed Computer Science's subject matter [1, pp 154—155]. These three items can be correlated with the later established Computer Engineering, Computing Science, and Information Systems. The ACM committee also chose to label the area Computer Science, instead of information sciences or data management [1 p 153].

The areas mentioned in Curriculum 68 intersected with Mathematics (numerical mathematics and simulation), Engineering (process control), Information Systems (data processing, file management, and information retrieval), and other related areas, such as Philosophy, Linguistics, Industrial Engineering, and Management. The 1968 committee considered them essential to balance Computer Science programs.

The still blurred 1960s computing artefact was clearly subdivided in hardware, software, and systems during the 1970s. This subdivision was accompanied by a disciplinary segmentation chain in which engineers build hardware, computer scientists write software, and information technologists deploy and maintain the resulting systems within organizations. As time passed, educational and professional practices in these fields became

increasingly insular. We should stress that the insularity is apparent in terms of disciplinary relations. It worked and it was indeed effective because it has been co-developed with a broader division of labour actualised by other segments. During the 1970s the disciplinary segmentation stabilized. Each specialization became reified across educational institutions and their enacted curricula, across industry and commerce and their organizations, and across governments with policies and resources.

Later on, in Curriculum'78, the committee did not give a definition of Computer Science, but it listed four groups of topics considered fundamental to Computer Science: (a) programming topics, (b) software organization, (c) hardware organization, and, (d) data structures and file processing. In terms of disciplinary relations, this definition enabled (a) a Computer Science focus on programming topics and software organization, (b) an interface with Electrical Engineering through hardware organization, and (c) an interface with Information Systems through data structures and file processing, respectively. We should remark that Curriculum'78 has partially guided the establishment of many Computer Science programs across North America. Curriculum'78 has been criticized for its excessive emphasis on programming. What is usually not mentioned is that, although the core was very narrow and restricted mostly to software, Curriculum'78 had a course on Computers and Society. However, most universities never implemented it.

With the further transformation of Informatics, people started to question the appropriateness of this disciplinary organization. Since the 1980s and 1990s, there have been several attempts to increase, or rescue, some of Informatics' initial breadth and resilience. For example, although Curriculum 68 had several courses in mathematics, Curriculum'78 did not have mathematics in its core set of courses. Its absence was immediately criticized by Ralston and Shaw [12, 13]. As in the Denning report [4, p 16], the excessive emphasis on programming was also criticized in Curricula 91 [2]. The 1991 committee wrote that the emphases given to different topics did not permit a balance between experimental and theoretical computer science [4, p 9]. A focus on algorithms rather than on programming was an attempt to rescue some of the field's initial orientation. This is clearly stated in Curricula 91.

The 1991 committee also stressed the "basic cultural, social, legal, and ethical issues inherent in the discipline of computing" [2, p 73]. As in Curriculum'78, the 1991 committee did not include such an area in the core courses of computing. The absence of social and ethical issues in Curricula 91 core courses did not pass by without notice. [6] proposed a complementation of Curricula 91, which included social and ethical issues as fundamental, known as the tenth strand. Many other criticisms have been

raised throughout the 1990s. Although computer engineers, computing scientists, and information systems technologists shared interests, daily practice had not fostered much interaction among them beyond their established roles and enacted disciplinary interfaces.

It is interesting to note that the emergence of fields such as Software Engineering and Human-Computer Interaction happened during a period in which some specializations in Informatics were acquiring recognition and stability by narrowing their breadth and increasing their depth. Although Software Engineering is often characterized as between Computer Engineering and Computing Science, a close analysis of its proposed body of knowledge unveils a set of topics related to people and organizations such as cognitive science, project management, and management. These topics have been part of Information Systems and Information Systems Management [5, 11].

The emergence of new areas of study, professional occupations, quarrels on established boundaries, inter-disciplinary work, all indicate that Informatics' traditional disciplinary organization is becoming inadequate. There is no recipe to reorganize Informatics, but individuals and committees have already expressed their opinions on how to renew and reorganize the field. In 2000 an IEEE-CS ACM joint task force recognized the "expanding" scope of the profession. Curricula 2001 reflect this concern. The committee has already expressed the view that the sustained narrowing tendencies of prior similar recommendations are currently inadequate. Indeed the task force began its work with a restricted scope of Computing Science and Engineering, as in the Curricula 91.

In Figure 2, disciplinary breadth variations are depicted in relation to the traditional branches of Informatics. The narrowing and expanding tendencies are delimited by two lines. The approximate scopes of several documents have been abstracted to depict the overall dynamics. The ellipses in Figure 2 depict the approximate perspectives adopted by professionals and committees. See Merkle [7] for references. Some professionals, such as David Parnas, tend to reinforce boundaries, others, such as Peter Denning and Wolfgang Coy, tend to blur them. The same can be said about professional associations. The bolder lines depict the approximate Computing Science domain projected on the technical dimension. The lighter lines depict Computer Engineering and Information Systems boundaries. Figure 2 depicts only a small subset of the actual disciplinary diversity present in Informatics. It is limited to three branches and their relations are reduced to a linear scale, which oversimplifies their actual intricate relationships. Other dimensions are required in order to discuss areas such as Human-Computer Interaction and Software Engineering.

Figure 2. Scope of Computing Science's nebulae of interests across its development

3. CONCLUSIONS

The development of a field, a profession, a discipline, a research topic happens not only at its centre or focus, but also on its boundaries and beyond them. However, the successes of Informatics are not enough to justify the over-specialization of its professionals. Current research trends and professional criticisms can be characterized as having or demanding foci that go beyond Informatics' recognized traditional branches. One of the challenges ahead is to overcome the orthodoxy consolidated in professional practices.

The disciplinary diversity found in Informatics' Curricula recommendations suggests that across its initial history several areas and subjects were left out of its concerns. In contrast with the few areas that have been consolidated throughout its development, a myriad of occupations has emerged during the last decade. In 2001, Denning listed thirty-eight areas [3] as part of Information Technology. In this article we have not discussed the reasons behind the inclusion or the exclusion of either the new or the now old.

The future pattern of Informatics' disciplinary development is an open question. The established view would say that it would continue to diversify monotonically, but this is an oversimplification. The short period analysed in this article suggests that the variations may be cyclic. This assumes that only part of the current diversity will develop the required depth that a discipline demands to be consolidated. Areas such as Human-Computer Interaction and Software Engineering give indications that there is cross-pollination with disciplines often housed in the social sciences, such as psychology and management.

Extrapolating the current tendencies, we would speculate that the respective human and process-centred approaches will be consolidated in a next cycle of development, being indeed incorporated into mainstream Informatics. Currently less diffused tendencies are those conjoint with the Arts, and Humanities, such as software design, computer semiotics, and social informatics, among others. It is our opinion that it would be wonderful if the involved communities were able to build bridges between these heterogeneous and usually separate fields. However, taking a conservative but critical stand, we believe that these bridges will demand more than one cycle to be structured and consolidated.

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