Information Science

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This essay is a personal analysis of information science as a field of scientific inquiry and professional practice that has evolved over the past half-century. Various sections examine the origin of information science in respect to the problems of information explosion; the social role of the field; the nature of "information" in information science; the structure of the field in terms of problems addressed; evolutionary trends in information retrieval as a major branch of information science; the relation of information science to other fields, most notably librarianship and computer science; and educational models and issues. Conclusions explore some dominant trends affecting the field.

Introduction

This is an essay. As are all essays, it is a personal analysis and expository of a specific topic—in this case, information science as a field. This is a critical reflection on the evolution and relations of information science from several perspectives, including historical, sociological, philosophical, technological, educational, and interdisciplinary. The purposes are to contribute to an understanding of the past and present of information science, and to assess the issues in its future. By definition, an essay is not a formal treatise. Essays allow for introspection and more flexible exploration than treatises, with conclusions that may be considered as hypotheses and suggestions for more formal studies.

1962. That is the year I began to work in information science, starting my professional practice in information retrieval (IR). After a few years I switched from practice to research and teaching in information science, which are activities that I have been pursuing for over three decades. Throughout, I was curious not only about a variety of specific problems that I was researching and teaching, but also about the "bigger" picture. I had a broader curiosity about information science as a field. This essay is an outgrowth of personal experiences and searches for the understanding of the larger framework of my own work and the work of my colleagues who profess to belong to information science. It follows in the footsteps of my other works related to the same topic (Saracevic, 1979a,b, 1992, 1995, 1997), integrating many ideas expressed there.

Approach

What is information science? The question, while seemingly simple, begs another, more complex one: *How is information science, or for that matter any field, to be defined?* This is a complex problem dealt with at length in philosophy and in other fields. Lexical definitions are necessary for providing a broad description and boundaries of the subjects covered by a field, but they cannot provide for a deeper understanding. Webster does not a field define. This is not to reject clear lexical definitions—not at all—just to establish their limitations.

In approaching the discussion of information science, I am taking the problem point of view as elaborated by Popper (1989, p. 67) who argued that:

> [S]ubject matter or kind of things do not, I hold, constitute a basis for distinguishing disciplines. . . .*We are not students of some subject matter, but students of problems*. Any problem may cut right across the border of any subject matter or discipline. (Emphasis in the original)

My emphasis is on problems addressed by information science. Although I provide definitions of information science and other fields in interdisciplinary relations with information science later in the essay, I am doing this solely to advance the understanding of problems addressed by different fields and their relation to information science problems. Debates over the "proper" definition of information science, as of any field, are fruitless, and in expectations naive. Information science, as a science and as a profession, is defined by the problems it has addressed and the methods it has used for their solutions over time. Any advances in information science depend on whether the field is indeed progressing in relation to problems addressed and methods used. Any "fixing," if in order, will have to be approached by redefining or refocusing either the problems addressed, or the methods for their solutions, or both.

Information science has three general characteristics that are the leitmotif of its evolution and existence. These are shared with many modern fields. They can also be viewed as problem areas with which information science has to deal on a general level.

- First, information science is interdisciplinary in nature; however, the relations with various disciplines are changing. The interdisciplinary evolution is far from over.
- Second, information science is inexorably connected to information technology. A technological imperative is compelling and constraining the evolution of information science, as is the evolution of a number of other fields, and moreover, of the information society as a whole.
- Third, information science is, with many other fields, an active participant in the evolution of the information society. Information science has a strong social and human dimension, above and beyond technology.

A number of works that I freely consulted dealt with various historical aspects of information science. Among those works are Shera and Cleveland (1977), Bourne (1980), Herner (1984), Salton (1987), Cleverdon (1987), Swanson (1988), Lilley and Trice (1989), Farkas-Conn (1990), Buckland and Liu (1995), and Rayward (1996). Still, a comprehensive history of information science is a project for a future historian of science. As yet only historical pieces and different perspectives of pieces exist.

A history of any field is a history of a few powerful ideas. I suggest that information science has three such powerful ideas, so far. These ideas deal with processing of information in a radically different way than was done previously or elsewhere. The first and the original idea, emerging in 1950s, is *information retrieval*, providing for processing of information based on formal logic. The second, emerging shortly thereafter, is *relevance*, directly orienting and associating the process with human information needs and assessments. The third, derived from elsewhere some two decades later, is *interaction*, enabling direct exchanges and feedback between systems and people engaged in IR processes. So far, no powerful ideas have emerged about *information*, as the underlying phenomenon, or *"literature"* (as defined later), as the object of processing. However, one can argue that the idea of mapping of "literature," that started with exploitation of citation indexes in 1960s, may also qualify as a powerful idea.

In a nonhistorical sense this essay deals with these powerful ideas and with leitmotifs, as suggested above. They form a framework for understanding the past, present, and future of information science.

Origin and Social Context

Information science is a field that emerged in the aftermath of the Second World War, along with a number of new fields, with computer science being but one example. The rapid pace of scientific and technical advances that were accumulating since the start of the 20th century, produced by midcentury a scientific and technical revolution. A most visible manifestation of this revolution was the phenomenon of "information explosion," referring to the exponential and unabated growth of scientific and technical publications and information records of all kinds ("literature"), so masterfully synthesized and illuminated by de Solla Price (1963).

In a remarkable turn of events, the impetus for the development of information science, and even for its very origin and agenda, can be traced to a 1945 article by Vannevar Bush, a respected MIT scientist and, even more importantly, the head of the U.S. scientific effort during WWII (Bush, 1945). In this influential article, Bush did two things: a) he succinctly defined a critical and strategic problem that was on the minds of many, and b) proposed a solution that was a "technological fix," and thus in tune with

Scientist-Poets Wanted: I see the field of library and information science (L&IS) as highly centrifugal and greatly in need of high-quality syntheses. Library and information science has always been easy to enter by persons trained in other disciplines, particularly if they bring quantitative skills. The pattern has been many fresh starts by new entrants rather than strong cumulation. Nor is there full agreement as to which work is paradigmatic. Therefore, I would give warm encouragement to writers who show a talent for creative integration and criticism of ideas already embodied in the literature. Their efforts should indeed go into reading and organizing *existing* claims, rather than gathering new data.

I would particularly like to see books that attempt to organize whole segments of L&IS through some single, powerful metaphor or thematic statement—for example, the notion of "information overload" or the notion of "cumulative advantage." Since I think one of the scandals of the field is that there is no fat, standard textbook that we can all use and disparage, I would like to see ambitious people with backgrounds in literature or philosophy actually try to state what the canon is in L&IS—the writings that would be summarized in the textbook—and to justify their choices. If that is too Olympian, I would like critical explications of noted individual authors, such as Derek Price or Gerard Salton, by someone who reads them in full and interviews their disciples and critics, in the manner of a journalist. I suppose I am calling for persons who add the skills of a poet to whatever training we can give them as scholars or scientists—scientist-poets, if you will.

Why not try to recruit students with demonstrable skills as writers into our Ph.D. programs and then ask them each to write a short book at the absolute top of their bent? Ask them to do for us what John McPhee has done for geology or Steven Pinker has done for linguistics. Would it be possible for us to use as models of academic writing not the usual dull dissertations but Howard Gardner's *The Mind's New Science* or Sherry Turkle's *The Second Self* or Tom McArthur's *Worlds of Reference*? A talented newcomer might be asked to look into the problem of algorithmic synopsis of writings as it has occurred from Hans Peter Luhn's day to Henry Small's; or the problem of getting concise word-association maps—Lauren Doyle's "semantic roadmaps" of the early 1960s—onto the computer screen to help online searchers during an actual online search (instead of merely publishing them in journals). The latter is

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the spirit of the times. Both had wide appeal and Bush was listened to because of his stature. He defined the problem in almost poetic terms as "the massive task of making more accessible a bewildering store of knowledge." In other words, Bush addressed the problem of information explosion. The problem is still with us. His solution was to use the emerging computing and other information technology to combat the problem. But he went even further. He proposed a machine named Memex, incorporating (in his words) a capability for "association of ideas," and duplication of "mental processes artificially." A prescient anticipation of information science and artificial intelligence is evident. Memex, needless to say, was never built, but to this day is an ideal, a wish list, an agenda, and, some think, a utopia. We are still challenged by the ever-worsening problem of the information explosion, now universal and in a variety of digital formats. We are still trying to fix things technologically. We are still aspiring to incorporate Memex's basic ideas in our solutions.

A number of scientists and professionals in many fields around the globe listened and took up Bush's challenge. Governments listened as well and provided funding. The reasoning went something like this: Because science and technology are strategically important for society, efforts that help them, information activities in particular, are also important and need support. In the U.S., the National Science Foundation (NSF) Act of 1950 (P.L. 81-507) established NSF and provided a number of mandates, among them "to foster the interchange of scientific information among scientists in the U.S. and foreign countries" (Section 3(a)3) and "to further the full dissemination of [scientific and technical] information of scientific value consistent with the national interest" (Section 11(g)). The 1958 National Defense Education Act (P.L 85-864) (the "Sputnik act") enlarged the mandate: "The National Science Foundation shall. . .undertake program to develop new or improved methods, including mechanized systems, for making scientific information available" (Title IX, Section 901). By those mandates, an NSF division, which after a number of name and direction changes is now called the Division of Information and Intelligent Systems (IIS), has supported research in these areas since the 1950s. Importantly, the field-defining studies that NSF supported included, among others, Cranfield IR evaluation studies in the 1950s and 1960s, large chunks of SMART studies from the 1960s to 1990s, and now the Digital Libraries Initiatives. In the U.S., information science developed and began flourishing on its own in a large part due to government support by a host of agencies, as did many other fields. Historically, the support was a success—it was instrumental in creation of the whole enterprise of information science and even of the information online industry based on IR (Hahn, 1996). But to the credit of information science it kept growing on its own even after government support slackened substantially. This cannot be said of a number of other fields or areas that floundered after government stopped being their main source and resource.

Social Context

It is a truism to state that information was always important for any society in any historical period. But the role of information and its degree of importance differed. With the evolution of the social order to a "post-industrial" society (Bell, 1973), or "post-capitalist" society (Drucker, 1994), or what we now commonly also call "information society," knowledge and information is assuming an increasing central role in every aspect of life. The classic study by Machlup (1962), followed by a number of similar studies (summary in Martin, 1998), documented the startling structural changes in the economy and society as driven by the growth of information and knowledge production and processing. Popularly, they were summarized by Drucker (1994, p. 42ff):

> The change in the meaning of knowledge that began two hundred fifty years ago has transformed society and economy. Formal knowledge is seen as both the key personal and the key economic resource.. . . [K]nowledge proves itself in action. What we now mean by knowledge is information effective in action, information focused on results.. . . The actual products of the pharmaceutical industry is knowledge; pill and prescription ointment are no more than packaging for knowledge.

Addressing the problem of information explosion, information science found a niche within the broader context in the evolution of the information society. In its various manifestations and attempted solutions, the niche is getting broader and bigger. But by no means does information

the now-fashionable problem of visualization of literatures, which Katherine McCain and I discussed in the 1997 *ARIST*.

I call your attention to the fact that, just as we have no textbook, there has also never been a general account of our field published in the American trade press. There is no paperback you can give to your uncle at Christmas and say, "Here's what it's all about." It would be nice to work toward such an account, perhaps by offering a monetary prize in an ASIS competition. Someday there might even be a section labeled Information Science, as there is one now for Linguistics, in bookstores like Borders or Dillon's. Probably none of us will live that long, but one can dream.

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science hold a monopoly in that niche. As the importance of information is increasing in society, more and more resources and expenditures are channeled into various information-related activities. More and more research funds, projects, and initiatives are devoted to information in various disguises. It is not surprising then that more and more fields, researchers, professionals, and businesses are turning to information, and even "discovering" information. There is gold in information. Information science has many competitors—it may be even swamped by them.

What Is "Information" in Information Science?

In a scientific sense, the answer to the question is "We don't know." Yes, we can and do provide various lexical definitions of information, and we have an intuitive understanding of its meaning that we apply daily and widely. Thus, we do understand the message-sense in which we deal with information in information science. But that does not provide for a deeper and more formal understanding and explanation. Information is a basic phenomenon. For all basic phenomena—energy or gravity in physics, life in biology, justice in jurisprudence—the same "we-don't-know" answer applies. However, the investigation of the basic phenomena is proceeding—that is the basic point of all these fields. It is proceeding by investigating the *manifestations, behavior,* and *effects* of phenomena under question. While we do not know what information is, or what some of its derivative notions, such as relevance, may be, over the years we have learned a lot about their various manifestations, behaviors, and effects. And we are continuing to learn about them through scientific investigations.

"Information" has a variety of connotations in different fields. For instance, from the standpoint of physics and biology, a number of highly ambitious (and as yet unsuccessful) attempts have undertaken to explore information as a basic property of the universe (e.g., Stonier, 1997). In psychology, information is used, at times, as a variable dealing with sensory perception, comprehension, or other psychological processes. These senses of information are very different than the one in information science. In some fields, information science included, the notion of information is broadly associated with messages. For this sense, a number of interpretations exist, which are assumed in different theoretical and pragmatic treatments of information. We can present them as related, but differing manifestations of information in an ordered sequence or a continuum of increasing complexity.

Narrow Sense

Information is considered in terms of *signals or messages for decisions* involving little or no cognitive processing, or such processing that can be expressed in algorithms and probabilities. Information is treated as the property of a message, which can be estimated by some probability. Examples are information in terms of uncertainty in information theory, "perfect information" in game theory, or information as related to decision-making and market equilibrium in the theory of uncertainty and information in economics of information. The latter has been surveyed by Hirshleifer and Riley (1992), who provide this illustrative explanation: In the economics of uncertainty, an individual is assumed to act on the basis of current *fixed beliefs,* e.g., deciding whether to carry an umbrella based on one's present estimate of the chance of rain, while in the economics of information a person typically is trying to arrive at *improved beliefs,* e.g., by studying a weather report before deciding to take an umbrella. Information may be considered as causing a difference between fixed and improved beliefs. The value of information is calculated as the difference between the decision maker's expected utility of the decision made without the information, and the expected utility of the best possible choice in decision made after receiving and analyzing the information. The huge, and sometimes insurmountable, problem, of course, is estimating appropriate probabilities. A number of pragmatic applications follow this interpretation, such as computerized trading.

Broader Sense

Information is treated as directly involving *cognitive processing and understanding.* It results from interaction of two cognitive structures, a "mind" and (broadly) a "text." Information is that which affects or changes the state of a mind. In cases of information services, information is most often conveyed through the medium of a text, document, or record, e.g., what a reader may understands from a text or document. The interpretation by Tague-Sutcliff (1995, pp. 11–12) fits:

> Information is an intangible that depends on the conceptualization and the understanding of a human being. Records contain words or pictures (tangibles) absolutely, but they contain information relative only to a user.. . . Information is associated with a transaction between text and reader, between a record and user.

Broadest Sense

Information is treated in a context. That is, information involves not only messages (first sense) that are cognitively processed (second sense), but also *a context*—situation, task, problem-at-hand, and the like. Using information that has been cognitively processed for a given task is an example. In addition to other senses, it involves motivation or intentionality, and therefore it is connected to the expansive social context or horizon, such as culture, work, or problem-at-hand.

In information science, we must consider the third and broadest sense of information, because information is used in a context and in relation to some reasons. The point was implicitly understood from the beginning of information science, particularly as reflected in the practice of information retrieval. This interpretation of "information" in information science is not new. Such a broad interpretation of information that explicitly incorporates cognition and context was, among others, elaborated by Wersig and Neveling (1975) and Belkin and Robertson (1976). It is also implicit in the social role of information science.

The Big Picture: Structure of Information Science

Any field is structured along some distinct, larger areas or subdisciplines of inquiry or practice. Think of a number of areas (subdisciplines) of medicine, computer science, librarianship, and so forth. Information science is not an exception. It has a distinct, two-partite structure. A number of authors (among them Vickery & Vickery, 1987; Vakkari, 1996; Saracevic, 1997; and others), observed that the work in information science falls in two large areas or subdisciplines, each, of course, with further subareas or specialties. White and McCain (1998) conducted a monumental bibliometric study of the domain of information science by providing extensive analysis of co-citation patterns for 120 authors over a period of 23 years. Borrowing from White and McCain, visualize a map of information science as an ellipse with authors inside, distributed or clustered according to their connections. There are two large clusters at each end of the ellipse, with only a few authors spanning both. In other words, there are two major areas or subdisciplines. I liked their metaphor (ibid.):

> As things turn out, information science looks rather like Australia: Heavily coastal in its development, with a sparsely settled interior.

In one of the coastal sections (the left side in the White & McCain map), fall authors that worked on *analytical study of literatures; their structures; studies of texts as content-bearing objects; communication in various populations, particularly scientific communication; social context of information; information uses; information seeking and behavior; various theories of information and related topics.* As yet, there is no good label for that cluster. Some call it "information analysis." For simplicity, lets call this the *domain cluster,* as did White and McCain, although "basic" may be a good label. In the other coastal section (the right side of the map), are authors who concentrated on *IR theory and retrieval algorithms; practical IR processes and systems; human-computer interaction; user studies; library systems; OPACs; and related topics*. Let's call this cluster the *retrieval cluster,* although "applied" may also be a good label.

Basically, most of the areas in the domain cluster are about study of fundamental manifestations and behavior of phenomena and objects that information science is all about. They are centered on the phenomenon of information and its manifestations in literature. The retrieval cluster deals, by and large, with a variety of implementations, on both practical and theoretical levels. It is about implementation, behavior, and effects of the interface(s) between literatures and people, including, of course, all kinds of retrieval aspects.

Unfortunately, these two main clusters are largely unconnected. Only a very small number of authors spanned the two clusters. In other words, there are very few integrating works. The last text (that I am aware of) that undertook an integrative approach encompassing both clusters was by Vickery and Vickery (1987). A rare example of such an effort in research is the last work by Tague-Sutcliffe (1995), where she related the notion of informativeness with evaluation of IR systems. Several modern texts are specifically aimed at IR (e.g., Korfage, 1997), but none on information science as a whole. I dare to venture a prediction: fame awaits the researcher(s) who devise a formal theoretical work, bolstered by experimental evidence, that connects the two largely separated clusters, i.e., connecting basic phenomena with their realization in the retrieval world. And a bestseller is awaiting an author that produces an integrative text in information science. Information science will become a full-fledged discipline when the two ends are connected successfully.

The two clusters are not equally populated. The retrieval cluster has significantly more authors, not to mention total number of works. As in many other fields, more effort is expanded on the applied side than on the basic side. In part, this is due to availability of funds for given topics—not surprisingly, research goes after moneyed topics. By and large, over the last decade or so, major granting agencies funded only applied research in information science. For instance, I have been unable to identify a single grant addressing any of the topics in the domain or basic cluster from NSF Division of Information and Intelligent Systems since its preceding Division of Information Science and Technology was reorganized and included in the Directorate for Computer and Information Science and Engineering (CISE) in 1985. In de Solla Price's (1963) concepts and words, the domain cluster is "little science" (also called "attic and basement science"), while the retrieval cluster is "big science," and the connection between the two has presently no science.

Problems Addressed

General

Webster (and other dictionaries) routinely defines information science as "the science dealing with the efficient collection, storage, and retrieval of information." It is a general definition of problems addressed by information science. The definition follows pretty much an early and popular one given by Borko (1969), as a part of a wide discussion and controversy about the nature of the field in the 1960s.

More specifically, information science is a field of professional practice *and* scientific inquiry addressing the problem of effective communication of knowledge records—"literature"—among humans in the context of social, organizational, and individual need for and use of information. The key orientation here is the problem *of need for and use of information, as involving knowledge records.* To provide for that need, information science deals with specifically oriented information techniques, procedures, and systems.

To elaborate, the specific concentration of information science is on human knowledge records as *content-bearing objects*, in all forms, shapes, and media. The primary emphasis is on content of these objects, in terms of their potential for conveying information. "Literature" may be used as a generic term for these knowledge records, but "literature" has many other connotations (e.g., in humanities), thus requiring a careful restriction in its use in information science. Because of these connotations, "literature" will not become popular in information science. Realizing this, I am using the term here only as a shorthand, as did White and McCain (1997, 1998), when they elegantly stated:

> The proper study of information science is the interface between people and literature. . . . [Information science addresses] modeling the world of publications with a practical goal of being able to deliver their content to inquirers [users] on demand. . . . While many scientists seek to understand communication between persons, information scientists seek to understand communication between persons and certain valued surrogates for persons that literature comprises.

As mentioned, in all of this there is a technological imperative, reflected in efforts to take advantage of modern information technology. While information science is not about technology, the problem of providing effective computer applications pervades the field.

Following is a word on the extent and borders of information science. Focusing information science on the content-bearing properties of literature (as defined above), and on associated techniques and systems dealing with providing effective access to and use of literature, provides a restriction for information science. Thus, the field does *not* deal with great many other information systems, such as payroll, inventory, decision support systems, data processing, airline schedules, and a zillion others, nor does it deal with direct communication among and between persons. Information science is about a specific manifestation or type of information that defines its scope and its systems.

Information science, as many other fields, also involves a professional component. Starting in 1950s, the profession of information science grew from research and applications in IR, to become a powerful component of the field, and in many ways a leading one in respect to innovation (among others documented in Farkas-Conn, 1990; and Hahn, 1996). As in many other fields, there is an uneasy relation between the scientific or research-oriented component and the professional or practice-oriented one. The profession is responding in its own way to needs of its users and organizations, and chartering its own technological applications, many times independently of research advances, and even in different directions. At present, the connection and feedback between profession and research in information science is not as well established as it is in older fields, such as engineering or medicine. This is a serious inhibitor for progress of both.

More Specific

A number of authors (among them, those cited in the section on structure) suggested a breakdown of specific areas of information science, beyond the structural analysis offered above. The breakdown among different authors is in significant agreement, although the labels differ somewhat. I will take the breakdown and labels provided by White and McCain (1998). They provided a factor analysis of co-cited authors and extracted 12 factors as specialties. In descending order of how authors loaded, they labeled the specialties as:

Experimental information retrieval (IR);
Citation analysis;
Practical retrieval;
Bibliometrics;
General library systems theory (including library automation);
Science communication;
User studies and theory;
OPACs;
General imported ideas—other disciplines (cognitive science, information theory, computer science);
Indexing theory;
Citation theory; and
Communication theory.

While one may quibble with some of the classes and labels, these specialties provide a fairly accurate picture of problem areas in which information scientists worked over the past quarter of a century. Over time, there were shifts in emphasis and there were movements between specialties. Nothing is permanent. But these are the specialties of information science. New areas are clearly on the horizon. For the 1990s, I would suggest that the major new areas include interaction studies; searching of the Internet; multimedia IR; multilanguage IR; and digital libraries. These are prime examples of the new significant areas of concentration, not yet evident in the historical record. At the same time, the old area of experimental retrieval is blossoming like never before, courtesy of the Text Retrieval Conference (TREC), a government-sponsored mechanism for comparative evaluation of a variety of IR techniques and approaches that involves large test beds. IR was, and still is, the major and most populated area of information science. Thus, a separate discussion of IR follows.

Information Retrieval

In the early and mid-1950s, a critical mass of scientists, engineers, librarians, and entrepreneurs started working enthusiastically on the problem and solution defined by Bush. By 1960s this became a large and relatively well-funded effort and organized activity. Often, there were heated arguments and controversies about the "best" solution, technique, or system. These arguments brought on the tradition of evaluation, a major staple of IR research and development. What is now TREC started with Cranfield evaluations in the late 1950s and early 1960s. (For a historical note on Cranfield, see Cleverdon, 1987, who was the driving force behind these evaluations.) Remarkably, the basic evaluation principles developed then are still the underpinning of TREC today.

Calvin Mooers, an active and highly visible pioneer of information science, coined the term *information retrieval* in 1951. The term took hold, and today is a part of the English language. At that time, Mooers (1951) not only coined the term, but also defined the problems to be addressed:

> Information retrieval embraces the intellectual aspects of the description of information and its specification for search, and also whatever systems, techniques or machines that are employed to carry out the operation.

Today, we would add that IR also and particularly involves interaction (including users) in all of these, with all the contextual—cognitive, affective, situational—aspects that interaction embraces. An expanded Mooers' conception is still valid. As it advanced, IR produced a number of theoretical, empirical, and pragmatic concepts and constructs. Numerous IR systems were developed and successfully deployed. A great many historical examples can be given to illustrate the remarkable evolution of IR systems and techniques, adapting the ever-evolving information technology, from punch cards in the midcentury to the Internet at its close. Based on IR, an online information industry emerged in the 1970s, and grew through its own version of information explosion, as chronicled by Hahn (1996). IR is one of the most widely spread applications of any information system worldwide. It has a proud history. Surely, information science is more than IR, but many of the problems raised by IR or derived from objects and phenomena involved in IR, are at its core.

Approaches and Paradigm Split

The approach taken by Mooers (and many other pioneers such as Mortimer Taube, James Perry, Allen Kent, Hans Peter Luhn, and a score of others) was to concentrate on the building of systems. This systems emphasis (or *systems-centered approach*), which was formulated early in the 1950s, was the sole approach to IR for some decades. It still predominates in a good part of IR research to this day. Consequently, most of the IR research and practice concentrated on retrieval systems and processes. However, starting in the late 1970s and gaining steam in the 1980s, a different line of reasoning and research evolved—one that concentrates on the cognitive, interactive, and contextual end of the process. It addressed users, use, situations, context, and interaction with systems, rather than IR systems alone as a primary focus. The retrieval cluster started splitting into subclusters, as noted by White and McCain (1998), and before by others such as Saracevic (1992) and Harter (1992). We now have two distinct communities and approaches to research in the retrieval cluster. They became commonly known as *systems-centered* and *user-* (or *human-*) *centered.* Both address retrieval, but from very different ends and perspectives.

The split is not only conceptual, looking very differently at the same process, but also organizational. The systems-centered side is now mostly concentrated in the Special Interest Group on Information Retrieval (SIGIR) of the Association for Computing Machinery (ACM), while the user-centered cluster congregates around the American Society for Information Science (ASIS). Each has its own communication outlets—journals, proceedings, and conferences. There is less and less overlap of authors and works between the two outlets. We have two camps, two islands, with, unfortunately, relatively little traffic in-between.

The systems-centered approach is exemplified by work on algorithms and evaluation based on the traditional IR model, a model that does not consider the users or interaction. The massive research that evaluates a variety of IR algorithms and approaches within TREC is a culmination of this approach. In contrast, cognitive, situational, and interactive studies and models, involving the use of retrieval systems exemplify the human-centered approach. Following that approach, interactive models, differing significantly from the traditional IR model, started to emerge. Even in TREC, a group of researchers started an interaction track, but so far have a hard time conceptually and methodologically, thus demonstrating the difficulty in merging the traditional and interactive models and approaches.

Let me characterize, in a simplified way, the relationship between the two approaches or subclusters addressing different sides of retrieval. On the one hand, the human- (user-) centered side was often highly critical of the systems side for ignoring users and use, and tried valiantly to establish humans as the proper center of IR work (e.g., Dervin & Nilan, 1986; Harter, 1992). The mantra of human-centered research is that the results have implications for systems design and practice. Unfortunately, in most human-centered research, beyond suggestions, concrete design solutions were not delivered. On the other hand, the systems side, by and large, ignores the human side and user studies, and is even often completely ignorant of them. As to design, the stance is "tell us what to do and we will do it." But nobody is really telling, or if telling, nobody is listening.

As a rule, in systems-oriented projects, people and users are absent. Thus, there are not many interactions between the two camps. Let me provide some examples. A rough analysis of the 1997 (and 1998) SIGIR proceedings (counting only long papers) found only 3 (4) papers of some 34 (39) that dealt in some way with people and users; in the

ACM's Digital Libraries 1997 (and 1998) conference proceedings, of 25 (29) papers only 3 (4) mentioned people and users (and this is stretching it).

If one reads authors such as Dervin and Nilan (1986), and many of their successors, who champion the human-centered approach, one gets the impression that there is a real conflict between the two sides and approaches, and that there is an alternative way to the "dreadful" systems approach. In a way, this stance is a backlash caused by the excesses, failures, and blind spots of systems-centered approaches not only in IR, but also in great many other technological applications. Unfortunately, sometimes the backlash is justified. All of us who work on the human-centered side are not that dismissive of the systems side. But the issue is not whether we should have systems- *or* human-centered approaches. The issue is even less of human-*versus* systems-centered. *The issue is how to make human-* and *systems-centered approaches work together.* In this sense, a number of works have addressed integrating user-centered and systems-centered approaches in IR, but this has been discussed mostly by researchers from the user-centered side. Examples are works by Bates (1990), Belkin, Cool, Stein, and Thiel (1995), Fidel and Efthimidiadis (1995), and Robertson and Beaulieu (1997).

To reiterate, it is not one camp against the other but how can we incorporate the best features of both approaches and make them work jointly. The issue is how to deliver and incorporate the desired design features that will improve systems orientations toward users, integrate them with systems features, and use advantages provided by both, humans and technology. In other words, the issue is *putting the human in the loop* to build better algorithms and to exploit computational advantages (Paul Kantor, private communication). Real progress in information science, and by extension in IR, will come when we achieve this. Lately, the NSF has championed human-centered design involving an interdisciplinary approach to information systems. Hopefully, this will go beyond rhetoric. It is not easy to do. But, that is what research is for—to address difficult, not only easy problems.

Proprietary IR

By the 1980s, the commercial information industry based on IR became successful and profitable. Out of academe, grants, and government, IR became a money-making proposition. This, of course, is another and important sign of success. Not surprisingly, a number of former IR researchers, practitioners, and graduates of IR programs ventured out to become IR entrepreneurs. Sure enough, throughout information science history there were many entrepreneurs, and they were highly significant in development of the field. But this generation of entrepreneurs was different. They ventured to develop and market a variety of IR procedures based on algorithms, applicable and scalable to large files, multiple applications, and/or various advanced technologies. It was knowledge industry at its purest. But, as in all commercial knowledge industries, the product was proprietary. While it was not that hard to guess the base of these various proprietary algorithms and how they worked—after all they were derived from publicly available knowledge and experiences, such as those that came from SMART experiments—they remain unpublished and "secret." A new kind of IR evolved, separate from the rest, not communicating as to intellectual advances with the rest. None of these ventures became a high commercial success, as measured by Silicon Valley standards. But the World Wide Web, emerging in the first half of the 1990s, changed all this.

The acceleration of the growth of the Web is an information explosion of the like never before seen in history. Not surprisingly then, the Web is a mess. No wonder that everybody is interested in some form of IR as a solution to fix it. A number of academic-based efforts were initiated to develop mechanisms, search engines, "intelligent" agents, crawlers, and so forth, to help control the Web. Some of these were IR scaled, and adapted to the problem; others were a variety of extensions of IR. Many had few, if any original, developments, besides new packaging or labeling; and a good number were just the usual hype. The wheel was reinvented a number of times. But out of this, and fast, came commercial ventures, such as the pioneering Yahoo!, whose basic objective is to provide search mechanisms for finding something of relevance (the notion is still there) for users on demand. And to make a lot of money. These enterprises pride themselves on having proprietary methods by which they are accomplishing the retrieval tasks. The connection to the information science community is tenuous, and almost nonexistent. The flow of knowledge, if any, is one-sided, from IR research results into proprietary engines. The reverse contribution to public knowledge is zero. A number of evaluations of these search engines have been undertaken simply by comparing some results between them or comparing of their retrieval against some benchmarks. Some evaluations were done within, others outside of information science (e.g., evaluation by Lawrence & Giles (1998) that attracted a lot of attention). Results were not complimentary. The Web-based proprietary IR is expanding and flourishing outside of the field. It is addressing a vexing problem, the like we have not seen before. But as yet, the success is elusive and questionable.

Relevance

As information science pioneers developed IR processes and systems in the 1950s, they defined as the main objective retrieval of *relevant* information. Effectiveness was expressed in terms of relevance. From then to now, IR is explicitly geared not toward any old kind of information, but toward *relevant information*. Various IR approaches, algorithms, and practices were, and still are, evaluated in relation to relevance. Thus, relevance became a key notion (and a key headache) in information science. It is also a complex phenomenon with a long and turbulent history in information science transcending IR, going back to early 1950s (Saracevic, 1975, 1996; Schamber, 1994).

Of course, there was a choice. Relevance did not have to emerge as the key notion. Uncertainty (as in information theory and decision-making theory) was one choice suggested by a number of theorists to be the base of IR, and thus to reflect effectiveness. But it did not take. In contrast, uncertainty is the basic notion underlying expert systems. If the pioneers had not embraced relevance, but instead, let's say, uncertainty, as the base for IR, we would have today a very different IR, and probably not that successful.

In general, relevance, according to *Webster*, means having significant bearing on matter at hand. As with many other concepts, relevance assumes related but more specific meaning in more specific contexts and applications. In the context of information science, relevance is the attribute or criterion reflecting the effectiveness of exchange of information between people (i.e., users) and IR systems in communication contacts based on valuation by people. With relevance as the criterion, and human judgments of relevance of retrieved objects as the measuring instrument, the measures of precision and recall are widely used in evaluation of IR systems. The strength of these measures is that they involve people—users—as judges of effectiveness of performance. The weakness is the same: it involves judgment by people, with all the perils of subjectivity and variability.

Relevance indicates a relation. For relevance, many relations have been investigated. An (uneasy) consensus has emerged in information science that we can distinguish between several differing relations that account for different manifestations or types of relevance:

System or algorithmic relevance: relation between a query and information objects (texts) in the file of a system as retrieved, or as failed to be retrieved, by a given procedure or algorithm. Comparative effectiveness in inferring relevance is the criterion for system relevance.

Topical or subject relevance: relation between the subject or topic expressed in a query and topic or subject covered by retrieved texts, or, more broadly, by texts in the system file, or even in existence. Aboutness is the criterion by which topicality is inferred.

Cognitive relevance or pertinence: relation between the state of knowledge and cognitive information need of a user and texts retrieved, or in the file of a system, or even in existence. Cognitive correspondence, informativeness, novelty, information quality, and the like are criteria by which cognitive relevance is inferred.

Situational relevance or utility: relation between the situation, task or problem at hand and texts retrieved by a system, or in the file of a system, or even in existence. Usefulness in decision making, appropriateness of information in resolution of a problem, reduction of uncertainty, and the like are criteria by which situational relevance is inferred.

Motivational or affective relevance: relation between the intents, goals, and motivations of a user and texts retrieved by a system, or in the file of a system, or even in existence. Satisfaction, success, accomplishment, and the like are the criteria for inferring motivational relevance.

Practically, IR systems assess systems relevance only—that is, they respond to queries—hoping that the objects retrieved may also be of cognitive relevance, and even more so of utility. However, a user may judge an object by any or all types of relevance—for a user they may interact dynamically. Difficulties arise when an object is of system relevance but not of cognitive relevance or utility, or conversely. If items are of cognitive relevance or utility, but were not reflected in the query, they are not and cannot be retrieved. At the bottom of IR research is a quest to align systems with other types of relevance.

People all over have a strong intuitive understanding of relevance, thus, they intuitively understand, without manuals, what IR is all about. This makes IR systems generally understandable and acceptable—a critical attribute in their widespread application.

Disciplinary Relations

Two things introduced interdisciplinarity in information science. First and foremost, the problems addressed cannot be resolved with approaches and constructs from any single discipline—thus, intedisciplinarity is predetermined, as it is in many modern fields. Second, interdisciplinarity in information science was introduced and is being perpetuated to the present by the very differences in backgrounds of people addressing the described problems. Differences in background are many; they make for richness of the field and difficulties in communication and education. Clearly not every discipline in the background of people working on the problem made an equally relevant contribution, but the assortment was responsible for sustaining a strong interdisciplinary characteristic of information science. I will concentrate on interdisciplinary relations with two fields: librarianship and computer science. Obviously, other fields, most notably cognitive science and communication, have also interdisciplinary relations, but these are the most significant and developed ones.

Librarianship

Librarianship has a long and proud history devoted to organization, preservation, and use of graphic records and records in other media. This is done through libraries not only as a particular organization or type of information system, but even more so as an indispensable social, cultural, and educational institution whose value has been proven manifold throughout human history, and across all geographic and cultural boundaries. Shera (1972) defines the library as:

> . . .contributing to the total communication system in society.. . . Though the library is an instrumentality created to

> maximize the utility of graphic records for the benefits of society, it achieves that goal by working with the individual and through the individual it reaches society.

The common ground between library science and information science, which is a strong one, is in sharing of their social role and in their general concern with effective utilization of graphic and other records, particularly by individuals. But there are also very significant differences in several critical respects, among them:

(1) Selection of problems addressed and the way they were defined—a majority of the problems listed above were not and are not addressed in library science;
(2) Theoretical questions asked and frameworks established—the theories and conceptual frameworks in librarianship (mostly based on philosophy and some on communication) have no counterpart in information science, and vice versa;
(3) The nature and degree of experimentation and empirical development and the resulting practical knowledge and competencies derived—there is very little overlap in experimentation and development between the two, and professional requirements differ as well to a significant degree;
(4) Tools and approaches used—a most telling example is the very different approach undertaken in relation to utilization of technology in IR and in library automation; and
(5) The nature and strength of interdisciplinary relations established and the dependence of progress on interdisciplinary approaches—librarianship is much more self-contained.

All of these differences warrant a conclusion that librarianship and information science are two different fields in strong interdisciplinary relations, rather than one and the same field, or one being a special case of the other. This is not a matter of turf battles, or of one being better or worse than the other. Such arguments, while common between many fields, matter little to progress of either field. But differences in selection and/or definition of problems addressed, agenda, paradigms, theoretical base, and practical solutions *do* matter. Thus the conclusion that librarianship and information science, while related, are different fields. The differences are most pronounced in the research agenda and directions. Interestingly, research on OPACs, now that they are incorporating more and more IR features, is bringing the two fields in closer relation. Probably, so will the research in digital libraries, but at this time (1998), it is too early to tell. The conclusion is not without heated controversy. Among other authors, Vakkari (1996) contends on information science and librarianship being one and the same field, with the now commonly used name of "library and information science." Does it matter? Administratively yes, very much so, particularly in universities and professional societies. Otherwise, no. The issue is, and always will be, in the problems addressed and solutions undertaken. I contend that they differ significantly.

Computer Science

The basis of relation between information science and computer science lies in the application of computers and computing in IR, and the associated products, services, and networks. In the last few years, this relation also involves research on the evolving digital libraries, with their strong technological base. To illustrate the connection, I use a definition by Denning et al. (1989):

> The discipline of computing is the systematic study of algorithmic processes that describe and transfer information: their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all of the computing is: "What can be (efficiently) automated?"

Computer science is about algorithms related to information interpreted in the first, narrow sense above, whereas information science is about the very nature of information and its use by humans, interpreted in the third or broadest sense. Computer science is about symbol manipulation, whereas information science is about content manipulation, where symbol manipulation is the indispensable infrastructure. The two concerns are not in competition, they are complementary—they lead to different basic and applied agendas. Computer science is also many times larger than information science.

A number of computer scientists have been involved in research and development on information and its many spin-offs, to the point of being recognized leaders in information science. Gerard Salton is a prime example. In addition, there are several streams of research and development in computer science that had no connection with the early evolution of information science, but have addressed information problems similar to those in information science. Among others, these include works on expert systems, knowledge bases, hypertext, and human-computer interaction (which is also a strong area in cognitive science). More recently, this involves research and development on digital libraries, a "hot," financially heavily supported area by a host of government agencies in the U.S. and many other countries. Bolstered by heavy support, interest in digital library research exploded on the scene in 1990s, attracting the attention of computer scientists from a wide variety of streams, as well as people from many other disciplines. These areas have a significant informational component that is associated with information representation, its intellectual organization, and linkages; meta-information, information seeking, searching, retrieving, and filtering; use, quality, value, and impact of information; evaluation of information systems from user and use perspective; and the like—all traditionally addressed in information science.

Conversely, these streams of computer science research and development provide a different outlook, framework, and approach, and even a different paradigm, not only for information science research and development, but also for its academic and continuing education. Again, as with librarianship, the issue is not about turf. It is about paradigms, theoretical foundations, and pragmatic solutions; and ultimately, it is about their appropriateness to human information problems.

Education

That education is critical for any field is a truism that hardly needs to be stated. In particular, research lives by education, it cannot be better than the education that researchers receive and then extend and plow back into education. Unfortunately, education in information science has not received the attention that it deserves. This may explain the many difficulties in the field that I have discussed. Educational models that evolved differed to a degree or even substantially from country to country. I am concentrating here on the U.S. models only. In the United States, two educational models evolved over time. I call them the Shera and Salton models, after those that pioneered them. Both have strengths and weaknesses.

Jesse H. Shera (1903–1982) was a legendary library school dean from the 1950s until the 1970s at Western Reserve University (later Case Western Reserve). Among others, he was instrumental in starting the Center for Documentation and Communication Research in 1955. Shortly thereafter, the library school curriculum started to include courses such as "Machine Literature Searching" (later to become "Information Retrieval"), and several other more advanced courses and laboratories on the topics of research in the Center (Shera, 1972). The basic approach was to append those courses, mostly as electives, to the existing library school curriculum, without modifications of the curriculum as a whole, and particularly not the required core courses. Information science (or a variation of the name) became one of the specialty areas of library science. The base or core courses that students were taking rested in the traditional library curriculum. Information science education was an appendage to library science. A few attempts to spin off information science as an independent degree and curriculum were not followed widely (Saracevic, 1979a). But Shera's model was. Library schools in the U.S. and in many other countries imitated Shera's model. They used the same approach and started incorporating information science courses in their existing curriculum as a specialty. Out of this was borne the current designation "library and information science." Shera's model is still the prevalent approach in schools of library and information science. The strength of the Shera model is that it posits education within a service framework, connects the education to professional practice and to a broader and user-oriented frame of a number of other information services, and relates it to a great diversity of information resources. The weakness is a lack of a broader theoretical framework and a total lack of teaching of any formalism related to systems, such as development and understanding of algorithms. The majority of researchers in the human-centered side, as I described earlier, came from or are associated with this educational environment.

Gerard Salton (1927–1995) was first and foremost a scientist, a computer scientist, and the father of modern IR. (Salton's research and educational approach is summarized in reminiscences by several of his students in the issue of *SIGIR Forum* (1997) dedicated to Gerard Salton). As such, he pioneered the incorporation into IR research a whole array of formal and experimental methods from science, as modified for algorithmic and other approaches used so successfully in computer science. His primary orientation was research. For education, he took the time-honored approach of a close involvement with research. Salton's model was a laboratory and research approach to education. As Shera's model resulted in information science education being an appendage to library science education, Salton's model of IR education resulted in it being a specialty of and an appendage to computer science education. Computer science students that were already well-grounded in the discipline, got involved in SMART and other projects directed by Salton, worked and did research in the laboratory, completed their theses in areas related to IR, and participated in the legendary IR seminars. They also published widely with Salton and with each other, and participated with high visibility in national and international conferences. From Harvard and Cornell, his students went to a number of computer science departments where they replicated Salton's model. Many other computer science departments in the U.S. and abroad took the same approach. The strength of Salton's model is that it: a) starts from a base of a firm grounding in formal mathematical and other methods, and in algorithms, and b) relates directly to research. The weakness is in that it: a) ignores the broader aspects of information science, as well as any other disciplines and approaches dealing with the human aspects that have great relevance to both the outcomes of IR research and the research itself, and b) does not incorporate professional practice where these systems are realized and used. It loses users. Consequently, this is a successful, but narrowly concentrated education in IR as a specialty of computer science, rather then in information science. Not surprisingly, the researchers in the systems-centered approach came out of this tradition.

The two educational approaches are completely independent of each other. Neither is connected to the other. Neither reflects fully what is going on in the field. While in each model there is an increase in cognizance of the other, there is no educational integration of the systems- and user-centered approaches. The evident strengths that are provided by Shera's and Salton's model are not put together. Their weaknesses are perpetuated. It is high time for communities from each model to try to integrate education for information science. It is an open question whether the human- and systems-centered approaches can fruitfully work together as urged in all those calls for human-centered design until an educational integration occurs.

While library education receives formal attention from the American Library Association (ALA), and education for computer science from ACM, no such formal attention is paid by any professional/scientific society to education for information science, or for IR in particular. Neither ASIS nor SIGIR, as primary homes for information science, have been involved to any great extent in educational matters, such as setting of standards (ALA approach) or devising model curricula (ACM approach). Clearly, there is a need and an opportunity for more substantive involvement by both organizations in educational issues.

Conclusions

We live in a society where knowledge and information are a dominating characteristic. No wonder then that many fields, many projects, many scientific, technical, social, cultural, political, commercial, and related activities try to deal with some or other dimension of knowledge and information. Many fields are in the race. Information science is one of them. Information is also a prized commodity, thus increasingly information is also becoming big business. Information science has many strong and diverse competitors.

We are an important part of these efforts because we deal not only with the growing avalanche of artifacts, knowledge records, or objects, but at the same time we deal with people who need, use, and interact with these records for their livelihood and problems. It is so much easier to think of and deal with artifacts, technology, and systems alone, and assume the users, which is the same as forgetting them. It is easier to lose sight of those toward whom all this is directed. But we also have to learn and constantly relearn a basic lesson that resulted from numerous studies and experiences:

> The success or failure of any interactive system and technology is contingent on the extent to which user issues, the human factors, are addressed right from the beginning to the very end, right from theory, conceptualization, and design process on to development, evaluation, and to provision of services.

However, increasingly we see a discontinuance between information science efforts that deal with systems from those that deal with users or human beings in general. A primary example is the increasing separation of works in IR done under the auspices of computer science, exemplified by SIGIR and digital library research. Computer science is about algorithms, computing, and technology, and it is not, and was not meant to be, human-friendly. There is absolutely nothing wrong with that when we look at the discipline proper—it is primarily focused on computing and computers not humans. However, when we look at problems and related applications where people are critically involved, when addressing them computer science has developed a tradition of behaving as a colonial discipline, with all the classic implications. This is starkly evident not only in the current TREC- and SIGIR-type IR research, but even more so in the digital libraries research, as formulated and carried out by NSF in the First Digital Libraries Initiative. Humans, toward whom all this is directed, are conspicuous by their absence. However, in numerous instances, both computer science theory and applications have become human-friendly when they have moved outside of the colonial confine.

Conversely, the human-centered information science, as exemplified by ASIS, has lost its presence in the systems side. Are we evolving into two information sciences—plural? One that is computer science-based focusing on IR, digital libraries, search engines and the like, and the other that is information science-based, more attuned to interaction, users, and use, with little direct connection with development of systems, but still completely dependent on systems, thus, chasing them relentlessly.

In all of this, I am afraid that the greatest danger facing information science is losing the sight of users, of human beings. By concentrating on or chasing the systems, I am afraid that more often than not we have lost that sight. But I am also convinced that the greatest payoff for information science will come if and when it successfully integrates systems and user research and applications. Society needs such a science and such a profession.

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