INFORMATION SCIENCE

HISTORY

An understanding of contemporary information science rests on an accounting of three basic movements that have governed its presence in the last two decades of the past century and were given emphasis and impetus following the end of World War II. The work of the early documentalists centered on the classification, indexing, and cataloging of documents given new definition by Dewey and others. Meanwhile, automation provided the second claim to science by opening new avenues for machine processing of documents, aiding their acquisition, storage, retrieval, and dissemination. This movement was crystallized by the historic ascendance of space and a new scientific renaissance that accompanied it. The third movement involved an increase in the military and industrial sensitivity to the importance of information fueled by the demands of the Cold War, the ballistic missile threat, and the Cuban crisis. This was accompanied by significant advances in solid-state physics and electronic and electrical engineering. Contemporary information science is an amalgamation of these individual, interrelated developments.

There are a number of sources that illustrate the nature and interdisciplinary character and function of information science. These include research on the composition of human resource applied to it, the record of scholarly activity found in publications, and the dependency on theoretical, conceptual thinking that can be hypothesized to guide its development.

PROFESSIONAL STRUCTURE OF INFORMATION SCIENCE

In an extensive study supported by the National Science Foundation and conducted by the University of Pittsburgh in 1980, a survey of academic, governmental, and industrial organizations was conducted to determine the extent of individuals involved in information science activity. The study defined the information professional:

> An information professional may be differentiated from other professionals who may work with data by the fact that s/he is concerned with content the meaning applied to symbols) and therefore with the cognitive and intellectual operations performed on the data and information by primary user.

The survey identified 1.64 million information professionals employed in the United States, 7 in 10 (1.16 million) in the industrial sector, 2 in 10 (375,500) in state and local govern-

Table 1. Number of Information Professionals by their Primary Information Function Performed: 1980

Information Functions	Number of Information Professionals	Standard Error	Proportion of Information Professionals (%)
Management of information operations, etc.	273,900	26,100	17
Data/information preparation for others	213,500	36,800	13
Data/information analysis for others	257,100	35,300	15
Searching on behalf of others	92,000	10,000	6
Remaining operational information functions	272,700	112,800	17
Information systems analysis	265,800	60,600	16
Information systems design	103,400	25,100	6
Information research and development	20,200	6,900	1
Educating/training information workers	42,800	7,300	3
Other information functions	5,000	2,600	1
Function not specified	93,400	42,700	6
Total	1,641,000	224,000	100[a]

Source: *Occupational Survey of Information Professionals 1980*, University of Pittsburgh, in conjunction with King Research Incorporated.
[a] Percentages do not add to 100 percent due to rounding of figures.

Notes
1. Industry sector does not include industrial establishments reported by Dun and Bradstreet as having fewer than 50 employees (full time and part time), many firms found in standard industrial classifications deemed unlikely to employ information professionals, and a portion of the US banking industry.
2. State and local government sector does not include higher education institutions, several functional areas, and agencies with fewer than 50 full-time equivalent employees reported by Bureau of Census *Governments Tape 1977.*
3. Federal Government sector does not include military personnel or employees of intelligence agencies, Tennessee Valley Authority, Federal Reserve Board, judiciary branch, United States courts, Supreme Court, White House staff, and submitting offices that reported fewer than 50 full-time employees.
4. Colleges and universities sector does not include institutions with fewer than 50 full-time employees reported in the *Education Directory, Colleges and Universities, 1977–1978,* and federally funded research and development centers.

ments, and 1 in 10 (78,000) in the federal government or in colleges and universities (30,000). Table 1 reports the functions that these professionals performed.

PROFESSIONAL ACTIVITY

Another source for understanding the thinking and activity of information scientists can be obtained from special institutes and conferences held. Prominent among these are those sponsored by the US military as part of their research and development programs and the Advanced Study Institutes funded by the Science Division of the North Atlantic Treaty Organization (NATO).

The MITRE/ESD Congresses

In 1962, at Hot Springs, Virginia, the US military sponsored the First Congress referred to as *Information System Science.* The meeting provided an assemblage of a broad range of current scholars from a number of disciplines to address issues on the analysis and design of military command and control systems, then substantially influenced by significant advances in electronic and electrical engineering. The meeting provided the platform for an active discourse on prevailing concepts on information systems among international computer engineers, linguists, cyberneticians, psychologists, documentalists, and other theorists and practitioners. Two other meetings followed. These provided specific focus and emphasis to the discourses engaged in the first meeting. Many of the participants at these meetings were IEEE and ACM members; thus the activities of these professional associations reflected the interests that were represented at the military-sponsored meetings. The interest centered largely on the computer but there was a diversity of interest and applications as is indicated in Table 2.

NATO Advanced Study Institutes

In 1972 the Science Division of the North Atlantic Treaty Organization funded the first Advanced Study Institute in Information Science. NATO funding of this Institute is of particular significance to the development of information science. Individuals who selected participants and participants who were funded by these NATO institutes primarily represented the physical and space sciences. Information science was unknown and speculated to be synonymous with computer science. Thus, it was a particularly significant occasion when the Science Division of NATO included information science as a bona fide field in its category of sciences.

The NATO Institutes stressed four basic pillars to guide its deliberations, namely, the foundations of the science, systems theory, related technological advances, and educational objectives to support the development of the science. The basic composition of these Advanced Study Institutes are presented in Table 3.

PROFESSIONAL PUBLICATIONS

Report of field activity and research engaged in by those identified with information science is a source for capturing the essence of information science. There is a plethora of literature that can be recruited. Three professional journals, each specifically identified with information science(s) from 1994 to the present, were surveyed. Specific terms included in the titles of each of the articles in the index of each issue were listed and then tallied. The result from this effort led to an

Table 2. NATO Advanced Study Institutes in Information Science

Champion, PA (1972)	Aberystwyth, Wales (1973)	Crete, Greece (1978)	Bad Windsheim, Germany (1986)
Search for identity	Perspectives in information systems	System design in action	Information systems failure analysis
Nature of information	Nature and function of information	Terminology and philosophical issues	
	Nature of a science of information	Cognitive processes	
		Laws and principles	
Information technology	Information systems: Nature, design, and use	Design: Processes, applications, database organization, impact, resources	Systemic aspects of information system failure
	Use of information		Investigative methods for analysis of information system failure
Social impacts	Information technology and its impact of man and society		
Professional aspects	Professional aspects	Social issues	Human issues in failure analysis

extensive and broad listing of subject heading. Those subject headings that were included more than twice are presented in Table 4.

In 1983, Machlup and Mansfield published their book *The Study of Information: Interdisciplinary Messages.* This text was a fundamental advance to the science bringing to fore the thinking of a number of distinguished scholars identified with the field. Table 5 includes the titles of the respective contributions, illustrating the diversity of interest of the science.

Table 3. MITRE-ESD First, Second, and Third Congress in Information Science

First Congress	Second Congress (1964)	Third Congress (1966)
Concept of information		
Information aspects of military command organization	Information aspects of military command organization, organization for the design of information systems	Organization for design of military organization
Biological models of command automata		
Joint man–computer design processes	Man–computer decision processes	
Man–computer information transfer	Man–computer information transfer	Man–computer information interchange
Self-organizing and adaptive system		
Information systems simulated modeling techniques	Laboratory exercises and evaluation	Command system simulation and design
	Information systems simulation and modeling	Laboratory simulation of tactical systems and the question and criteria for tactical control: Field systems
	Tactical information system	Tactical command control: Field systems
		Tactical command and control compatibility
Intelligent automata		
Information system design techniques	Information system design techniques	
Joint man–computer languages	Information system languages	
	Towards computer control through natural languages	
Information system operational analysis	Information system analysis	Operational information system analysis
Programming information processing automata		
Joint man–computer indexing and abstracting	Document control	Text processing
Automated instructional techniques		
Information system performance		
Flexibility of automated information systems		
	Military data management system	
	Information requirements and use for research and development planning	
		Online man–computer interactive system
		Impact of automated information systems on organizations and missions
		Computer utility

Table 4. Key Work (KW) Sampling of Subject Content of Journals Representative of Information Science (1994–98)

Information Sciences P. P. Wang, Ed. Duke University *N* (KW) = 59	Information Science A. Gilchrist, Ed. Cura Consortium, UK *N* (KW) = 89	JASIS B. R. Boyce Louisiana State University *N* (KW) = 69
Queries	Legal issues	Article citedness
Fuzzy Sets	Information policy	Journal impact
Parallel Algorithms	Electronic writing	Electronic publishing
Databases	Information systems	Library book circulation
Rough sets	Information society	Information technology
Algorithms	Retrieval	Information services
B. Trees	Citation analysis	Information resources
Distributed objects	Electronic writing	Communication
Distributed systems	Database informatics	Multimedia
Entropy	Information technology	Spatial information
Files		Online learning
Programming		

THEORETICAL STRUCTURE OF INFORMATION SCIENCE

Three fundamental theoretical frameworks characterize the interdisciplinary activity of information science. These include the classification of literary transmission and communication, automata theory, and systems theory. These interrelate in many diverse ways. The influence of electrical and electronic engineering is most manifest in the theory of automaton and systems. Norbert Wiener's theory governing communication and control (cybernetics) borrows from early thinking by systems theorists (Boulding) merges automaton and systems in a distinct manner. Cybernetics is defined as a science dealing with the comparative study of complex electronic calculating machines and nervous system in an attempt to explain the nature of the brain (Webster's New World Dictionary, 1966, p. 365).

The pivotal issue that is implicit in cybernetics is that all living organisms are information systems. Furthermore, all organisms are limited in their capacity to deal with the external world due to the sensory and neural (brain) propensities of the organisms. Thus, it was important to matching human and machine capacities (symbiosis) to achieve efficient and effective achievement of goals and objectives.

Table 5. The Study of Information

Information science, its roots and relations as viewed from the perspective of cognitive science	Zenon W. Pylshyn
Informatics (computer and information science): its ideology, methodology, and sociology	Saul Gorn
Intellectual issues in the history of artificial intelligence	Allen Newell
Linguistics and its relations to other disciplines	Thomas G. Bever
Library and information sciences: disciplinary differentiation, comptition, and convergence	W. Boyd Rayward
Cybernetics	Murray Eden
Thirty years of information theory	Myran Tribus
On systems theory and its relevance to problems of information science	Hasan Mortazvian
Systems theory, knowledge, and the social sciences	Richard N. Langlois
Semantic quirks in studies of information	Fritz Machlup

Source: *The study of information: Interdisciplinary messages.* New York: Wiley, Interscience, 1976.

All organisms derive the awareness (information) of their condition through the sensory mechanisms available to them through evolution. This fundamental construct establishes the model (metaphor) upon which analysis and design of information systems—the major focus of information science—can be pursued. Within this conceptual envelope, it is hypothesized that many of the technological, engineering, and human aspects of information science can be realized and incorporated. This concept is represented in the six major subsystems of the overall information system.

Event Subsystem

Usually included as environment, input, stimulus, an event is an occasion, an experience in space and time. The event is the force (matter and energy) that drives the activity of each part of an information system. An understanding of the properties of events is fundamental to the interests of the information scientist attempting to derive principles and laws that govern the analysis and design of information systems. An understanding of events is offered by situation theorists who address a wide spectrum of theoretical and technical areas that pertain to events. These areas include the ontology (nature) of universes, situations as mathematical abstractions, the role of semantics, and the application of logic, language, and visual data as means for reasoning and analysis of events.

Sensor Subsystems

Human and technological sensors capture (acquire) the physical properties of the event. These properties are then coded and made available as data to be transmitted to human and technological processors directed at achieving information system objectives, using, for example, human awareness. However, sensors technologically provide the stimulus for instigating machine (computer) functions. The human as an observer can function as a sensor subsystem. She or he in this role is aided by a wide spectrum of electronic and optical technologies (binoculars, eyeglasses, hearing aids, etc). From a broader perspective, the human serving as a sensor functions as a monitoring, accounting, and regulating agent directing the course of various aspects of events, whether these be in sighting an iceberg, tornado, or crime, observing the gradual metamorphism of a microorganism, locating a book, or other human activity or experience.

Transmission Subsystem

One major interest of information scientists (analysts and designers) is the flow of data (signal) from the event to the various other components (subsystems) of an information system. Data transmission from one subsystem to another is a critical property of an information system and the most vulnerable to breakdown and failure. Electronics and electrical engineering have played an important part in attending to these encounters (black boxes in aircraft; security systems, etc.). Not until recently has teletransmission received the attention of information scientists corresponding to its importance. Meanwhile, the many advances in teletransmission made possible by electronics has raised important social issues. Quick and varied electronic access to data and information have spurred many social issues some of which include the privacy, censorship, moral code, copyright, and ethics.

Processing Subsystem

The conversion of matter and energy in a form that is useful and functional in achieving human purpose is of central interest to information scientists. Processing is a vital function of all organisms. This axiom applied to information science differentiates operationally its counterpart, namely computer science. While debate over definitions and disciplinary boundaries prevail, the substance of advances in automata clearly differentiates the properties of human and machine processing and relegates the primary interests of computer science to automata while information scientists center their interest on both.

The manner by which data from the processor (computer) is electronically displayed to an observer (user) is an area of importance to the information scientist. The electronic display incorporates many of the advances in electrical engineering. This is balanced to some extent by the attention of ergonomists (human factors and forensic specialists) and information scientists. The major challenge is to determine the organization of data on displays that can enhance human cognitive function, primarily decision making, problem solving, and learning.

Utilization Subsystem

Often the utilization component of an information system is ephemeral and transparent because of its cleavage with the processing subsystem. Yet, the utilization component has an identity of its own. Its primary role is the development of algorithms that facilitate efforts entailed in decision making and problem solving. Here cognitive science and information science seems to offer vague albeit similar or overlapping objectives. Attachment to cognitive science creates a degree of ambiguity as to the boundaries of emerging fields as cognitive science, artificial intelligence, and cybernetics. Basically, however, computer scientists provide a measure of coalescing if not confluence in their attention and use of technology in achieving system objectives.

Transfer Subsystem

This can be referred to as communications—the function that extends awareness to meaning and understanding. This in turn provides direct action on the event to which the information system is responsive. Again, electronic displays (cathode ray tubes, fiber optics, lasers) assume a center role as the important medium. Applications vary and extend from photography, holography, hypertext, virtual reality, and visualization and span all of the other sensory dimensions, namely, hearing, touch, smell, and kinetics (motion).

Because of its interdisciplinarity and youth, the theoretical and operational inclusivity, information science must remain tentative pending further coalescing of interest and purpose. Given the foregoing, future dependence and development of information science on electronics and electrical engineering is not a matter of conjecture.

BIBLIOGRAPHY

J. Barwise et al., Situation theory and its applications, in *Center for the Study of Language and Information,* vol. 2, Menlo Park, California.

K. E. Boulding, General systems theory—The skeleton of science in Management Science, Vol 2 (April, 1956b, pp. 197–2081).

Britannica Book of the Year, 1994–1998, Encyclopedia Britannica Inc. New York.

Anthony Debons et al., *The Information Professional: Survey of An Emerging Field.* New York: Dekker, 1981.

A. Debons, Foundations of information science, *Adv Comput.,* **30**: 307–360, 1996.

M. Dewey, *Classification and Subject Index for a Library,* New York: Forest Press, 1876.

F. Maclup and U. Mansfield, *The Study of Information: Interdisciplinary Messages,* New York: Wiley Interscience, 1976.

J. G. Miller, *Living Systems,* New York: McGraw-Hill, 1978.

A. M. Weinberg, Science, government and information: Responsibilities of the technical community and government in the transfer of information, *Report of the President's Advisory Committee,* 10 January, 1963, Washington D.C.: US Government Printing Office, 1963.

N. Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine,* Cambridge, MA: MIT Press, 1948.

ANTHONY DEBONS
University of Pittsburgh

INFORMATION SYSTEMS. See DOCUMENT HANDLING; VERY LARGE DATABASES.

INFORMATION SYSTEMS FOR QUALITY. See QUALITY CONTROL.

INFORMATION SYSTEMS MANAGEMENT. See MANAGEMENT INFORMATION SYSTEMS.