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Printed journals of scientific literature are likely to become extinct due to increase in prices and depletion of resources, etc. An alternative method discussed here is the adoption of an electronic journal. The new system allows both the rapid dissemination of large quantities of information and a close control over the quality of the information which is transmitted. It also saves time, money, and storage space.

Part of the obligation of any science is to make public the results of scientific investigation. The scientific component of printed matter has grown at an extraordinary rate even when compared with the growth of information and information flow in general in the last fifty years. However, it has been clear to many observers that scientific journals at some time are likely to become extinct merely because of the growth of the amount of information being distributed by journals and the consequent difficulty of retrieving that information from the library. Increase in prices and depletion of resources are other reasons why the journals cannot last indefinately. For example, the costs of raw materials for publishing are increasing faster than costs in other areas of industry. The costs and delays associated with the postal system in the presence of a rapidly increasing population have themselves changed (for the worse) more rapidly than many other aspects of society influenced by population size. In general, the situation will get worse, not better. Under such circumstances, the ideas of sociologists and their research and analyses are disseminated rapidly only to a small fraction of the potential readership. Only well-known authors are to be sent a preprint of the document. However, the document is usually uncitable in later work until it has been published, so that delays which may be as long as one year are built in to the successive generations of thought and research which stem from some fundamental idea.

As the printed journal distributed by the postal system becomes obsolete, a number of alternatives present themselves. One of these assumes that the journal will exist in its present form up to the point where it is printed and bound. It will then be made available in some microform (micro-film or micro-fiche) which will make significant savings possible, both in production and postage costs. Most of the delays, however, are still present. Further, the information contained in the scientific article remains subject to the skill of the indexer in selecting key words which adequately describe the informational content, and to the skill of the potential searcher who may wish to obtain that information in translating his desire into a set of key words which will, in fact, retrieve, not the information, but the document which contains it.

Two major difficulties of the present system stem from the problems of distribution of current issues and the retrieval of past information. In addition, there are a number of conflicting goals. On the one hand, people who do research wish to communicate quickly the results of their activities to other persons. On the other hand, a system of quality control has been developed which, by a process involving editors, associate editors, referees, anonymous comments, confidential critiques, etc., prevents below-standard research, poorly written reports, or improperly analyzed data from finding a way into the public domain. The system also delays the information on its way from "source to sink" so that "users, experiencing long delays, still complain that many papers are already obsolete before they appear," and "these lags are attrib-

utable to causes: increased demands on editors to process more manuscripts; the slowness with which manuscripts, galleys, and page proofs flow through the editorial review and postal systems; the time required for technical editing and page layout; and the long, often unpredictable, time consumed by printing, binding, and mailing" (Van Cott, 1970).

From many points of view, the saving of time and possible elimination of duplication aside, cost considerations alone suggest that some alternative method is inevitable. There are, of course, many alternatives, but I will consider in detail only one form of electronic distribution of readable material.

This electronic alternative assumes that the present form of the journal will disappear sometime and be replaced by completely electronic storage and retrieval of the alpha-numeric-graphic content of scientific articles. Publication, for example, might consist of electronic transmission to all subscribers via "teletype" (not really, but the word has the right connotation). One objection to such proposals when they have been advanced in the past has been that such transmission would be slow and prohibitively expensive. However, with the development of digital data networks, the cost is trivial for a user who has a suitable terminal in his institution. We can easily tolerate transmission cost, especially when all of the cost previously incurred in the gathering up of trees, and conversion of them into paper, the printing and binding of the paper, and the mailing of the printed journals to various places are eliminated all together. The question of past information with this form of publication system is dealt with later on.

Now let us examine the second goal: the preservation of quality. Consider the scientific communication process as it presently exists. Someone does a piece of research, gathers data, performs analysis, and then writes a paper, submits it to an editor and it is published. That is the simple way of looking at it. In reality things are somewhat different. The author gathers and analyzes his data; he writes a paper; he reads it and he rewrites it; he edits it and revises it again. Then he submits it to a colleague. The colleague looks at it with a critical eye, and returns it with comments. The author then rewrites or revises it and, finally, sends it off to a journal. The article is mailed to the editor who puts it at the bottom of the pile of papers awaiting his attention. Eventually, when he gets around to reading the title and the abstract (and possibly the whole text), he chooses an associate editor, or one of his referees, and mails it off to him. The referee may or may not agree to deal with this particular article. Let us assume that he does. He then has to find time to read and review it. These are difficult and time-consuming processes. The referee sends it back to the editor; the editor again puts it at the bottom of his "push-up list"; eventually he gets to it, looks at it, and sends it back to the author. If the author complies with all the suggestions made by the referees, the editor publishes the paper. To publish it, he sends it to the printer; the printer sets it in type, and one can imagine the rest. Eventually, after the galleys have been sent back, etc., the paper finds its way into the rather limited number of pages available to that journal for that year, and copies of that journal are distributed. The whole process may take one year, and sometimes up to two years.

The advantage of this system is that the articles that are so carefully processed and finally published in the highly respected journals are reliable work. The electronic alternative proposed is a system which can allow both the rapid transmission of large quantities of information from one place to another and still maintain a close control over the quality of the information which is transmitted.

In contrast to traditional journals, the electronic journal appears to have a relatively constant to slowly declining cost over the next twenty-five years. As Hecht (1976) writes: "Although the initial cost for an Electronic Journal is greater than that for paper journals, the projected cost pairs cross over during the next twenty-five years. The

exact date of the cross-over depends on the number of printed pages of material. A single journal of under 1000 pages (in 1975) with 3,700 subscribers has an estimated cross-over point in the late 1990s. The entire English language scientific journal output distributed world-wide reached a cross-over at the beginning of 1976." Intermediate numbers of assumed annual pages and subscribers yield intermediate cost cross-over points.

Let us consider the following scenario: The author goes through the same internal process in his institution. He writes, and rewrites, and edits, and submits for local criticism. He finally approves the copy; that is to say, he gets it to his secretary, or to the departmental secretary. He also selects an editor. The final typing is done on a machine that also makes a punched paper tape, for example. Having selected the editor, he puts the tape in the tape reader, types in the name of the editor, and through a variety of several processes (which really are not very difficult or magical at all) he sends the content to that editor. The title, abstract, and other useful information appear that day, or three minutes after midnight, or whenever, on the editor's display. In the morning when the editor comes in, he sees all the information there. After looking at the title and the abstract which have appeared, and at the institution and the author's name, he then may choose an associate editor, or two or three, and, using very simple typed commands, send the article to the associate editors. (If he desires text, he "calls" for it and it will be displayed for him.)

The title and the abstract appear on the associate editor's display. The associate editor either accepts or refuses to referee it. Let's assume he accepts. He then goes through the same process. He calls for the text, the figures, and everything else that goes into the article, and follows exactly the same procedures as he ordinarily does, but meanwhile we are already three or four weeks (perhaps even three or four months) ahead of the usual process. The associate editor makes his comments. (By the way, each line is numbered—a trivial exercise for the computer—so that any line can be referred to by number in the commentary of the associate editor.) Having completed his commentary, he transmits this back to the editor, merely by typing in "Editor," and it appears on the Editor's machine as a commentary, which the editor can then transmit (and he doesn't have to read it unless he wants to, though he more than likely will) back to the author. This, of course, can be repeated many times; but if the author complies, that is to say, rewrites in accordance with the considered judgment of the external referees, as perhaps filtered by the editor, he resubmits this material by merely transmitting it again. (The machine, by the way, will do all the interpolation, and will reorganize and renumber the lines, a simple action for the computer.) If the editor is satisfied, he types "Publish" and it is thereby published.

Now what does it mean to say "It is thereby published"? It means that the entire document of the scientific work has been entered into a magnetic store, numbered, with an author and a title, and an abstract or summary. The citation would also appear upon your display, since you subscribe to articles of that kind, i.e., the *keywords* are among those listed by you on your interest profile. If you want a full text, you get it, or you may call for any part of the complete information. For example, you may wish to call for the bibliography. (You want to know if you are cited; and if you are not, you immediately conclude that it is a mediocre article: its author wasn't aware that you had done the same work 16 years before and have been waiting for someone to cite you ever since.) You may want the "table of contents," or the summary, or just the conclusions—if your interest is in the application of the results. You may also ask for the raw data since you may have an alternative theoretical explanation or approach. Alternatively you may want the author's bibliography, since if this is an interesting article the author may have written other interesting papers. As can be seen, brows-

ing becomes much more productive than was previously possible without a staff of library researchers at command.

The electronic search and retrieval systems based upon computer readable bibliographic citation—and in some cases, an abstract content—already exist in a number of fields. Data bases containing information on physical and social sciences are accessible from any point in the world by persons with suitable terminal equipment. For modest cost, these data bases can be searched in various ways to yield useful, bibliographic information for the person doing research or investigating a particular problem. The use of computers for editorial processing is already well under development by the National Science Foundation and described elsewhere in this issue (Rhodes and Bamford, 1976). Electronic Editorial Processing centers for scientific journals are being tested experimentally at the present time. Its outcome is a computer-ready tape which, in the usual course of events, would go directly into a computer-controlled typesetter in order to set hot type, or phototype for use in the traditional printing process. Obviously enough, with a computer readable output stemming from the Electronic Editorial Processing center and with the availability of storage, search, and retrieval systems of the sort characterized by Psychological Abstracts et al., the intervening stage is a minor, albeit somewhat expensive, implementation problem. Rather than its being emitted to control a typesetting machine, one could imagine the "document," once accepted for publication, being stored in a capacious electronic memory. This memory would then be accessible from any point by "subscribers" to the particular serial publication. The "journal" would once again exist in its etymological sense; i.e., publication would be carried on every day. It would, in fact, be a continuous process, and the present form of separated subsections of the scientific literature now called journals would no longer be necessary. The search and retrieval mechanisms could be done as they have been in the past, by key words, or, with the advent of cheaper, more powerful systems, by direct consideration of the entire content of the scientific article.

Additional benefits can come from such a system. It was demonstrated in 1962 [1] that it is possible to store large quantities of alpha-numeric and graphical material in a digital computer; to recall these in a whole text search mode; to examine the graphical and quantitative content presented in the text; to manipulate the presented material according to different hypotheses about them; in short, to engage interactively with the linguistic, the quantitative, and the mathematical material presented in a document.

Many people have expressed fears that electronic offices will generate a generation of scientists who will sit at desks connected to remote machines and engage in intercourse with these machines to the exclusion of human interaction. Vannevar Bush had some great visions more than 30 years ago. Much of what he described can now be done, perhaps all of it and more. It is instructive to examine both the original and the "revisited" versions of Memex and to consider the advantages of the systems of that degree of complexity or greater (as is now possible). Most of us spend a large amount of time reading, and almost as much time bemoaning the fact that there is so much to read that we cannot possibly read it all. In addition, we are often forced to read what we do not want to read. The advantage, and it may be the overwhelming and forceful advantage, of the electronic alternative is that it will be possible to identify and locate the particular nuggets which in the past required so much mining. The electronic office is not a fearsome thing; a brief exposure to it is very convincing.

A system like the one described, or possibly some even more elaborate system, is almost inevitable given the joint pressures of volume of published scientific material and the cost of traditional ways of doing things. It would be wise for all established scientific investigators to act

[1] Personal observation at Bolt, Beranek, and Newman, Cambridge, Mass. The program was developed by J. C. R. Licklider.

now to influence and support these new systems and to shape them according to what they believe to be best for the journals of the future.

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