TWENTY THIRD BIRBAL SAHNI MEMORIAL LECTURE

Impact of information technology in scientific inquiry

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Professor Mohan Ram, Dr Tiwari and Friends,

When I first received a letter from Dr Tiwari requesting me to deliver the Founder's Day lecture of Birbal Sahni Institute of Palaeobotany, I thought it was a case of mistaken identity. At that time, I did not even know what was meant by Palaeobotany. Yet I did not decline the offer and kept the letter aside. I do not know why ? Perhaps it was the natural instinct to give a try to something new. When my office received a call from Dr Tiwari (I was not in the office at that time), I was sure that this was not the case of mistaken identity. I responded to the call by just saying that I had not made up my mind. Dr Tiwari persisted and called after two weeks or so once again. This time he caught me in the office, recalled our acquaintance in one of the Workshops organised by the Publications and Information Directorate (PID) of CSIR, and said that I should go over to Lucknow to give this lecture. I told him that I understand very little of botany itself and what to talk of Palaeobotany. In fact, I have a serious allergy to botanical names of plants and flowers. My head starts reeling when I hear those difficult and unfamiliar names. And, believe me, I may not be able to recall more than half-a-dozen botanical names for even common plants and flowers. Yet Dr Tiwari prevailed upon me and said that during the Founder's Day lecture, they would like to hear something from my field of specialisation, namely, Information Science. I had no option but to agree and promised him to send the title of my talk soon thereafter. Later I learnt that Professor Mohan Ram had been instrumental in getting me here for this talk. When I reflected on what I should speak about, I felt that I should convey my appreciation of how the current technology of information can help scientists in their quest for knowledge. This is how I chose to talk on the impact of information technology in scientific inquiry.

But before I speak on the proposed topic, I must mention that I am very impressed by my visit to the Institute this morning. After having learnt about the activities of the Institute, I can not but dwell upon at least a little bit about the ancient Indian knowledge. First let me take up the big bang theory of the formation of the Universe. In its simplest form, the theory says that the Universe started with a big bang from a egg-like shell and since then expanding continuously. In the first few seconds, the rate of expansion was so large that very little is known about the formation. Thereafter the rate of expansion slowed down and it continues to slow down further and further. The logical conclusion is that one day in the distant future, the rate of expansion would become zero and a process of contraction would start. Initially, the rate of contraction will be very low and increase as the time passes. After a very long time the rate of contraction may become so high that the whole universe will condense into the egg-like shell in a few seconds of time. Then there is no creation or universe. The egg-like shell may remain dormant for a very long time before it bursts forth once again with a big bang. Now compare this with our ancient theory of Pralaya and Mahapralaya. As per this theory, every cycle of creation has four Yugas in it; Satya Yuga, Tretha Yuga, Dwapara Yuga and Kali Yuga. The end of each of the first three Yugas is marked by land mass becoming water bodies and water mass becoming land body. This statement is not totally illogical. We know that along the riverine systems silting takes place and the silt is eventually deposited in the sea. A day may come when entire hills are eroded and deposited in the sea and hillocks are formed in the sea. During Mahapralaya everything is destroyed and the entire creation comes to a naught. In modern scientific terms, the ancient theory may be stated as follows :

> "The creation and dissolution of the Universe proceeds in cycles. Each cycle has four minor cycles in it. Each minor cycle is divided into four quarters. At the end of each minor cycle, life on the earth comes to an end and the water bodies and land masses are interchanged. At the end of a major cycle, the entire universe goes through a process of dissolution and everything reaches a state of inertness. After having been in the inert state for a long time, the Universe projects itself to start a new cycle".

How long has this creation been going on? This is a question of great interest to palaeobotanists. Answer for this seems to lie in our scriptures. Every day mantra that is chanted in many families even today in India talks of the present age being the part of the first quarter of the fourth minor cycle (Kali Yuga) of the 28th cycle of creation. According to Panchangas we appear to have spent over 5000 years in this quarter and over 1,25,000 years are still remaining as part of this quarter. These are interesting figures not to be brushed aside just like that. I would urge the palaeobotanists to verify the truth of these figures using their own methods like dating techniques, etc. I would like to take one more example to illustrate the efficacy of our ancient wisdom. This time, I pick up the Sanskrit language. In 1984, an article was written by an American in AI (Artificial Intelligence) magazine, which states that Sanskrit is ideally suited as an intermediate language for machine translation. That is, if we have to translate Japanese into English, first we translate Japanese into Sanskrit and then from Sanskrit to English. This model is shown in Text-figure 1a.

The use of intermediate language has a great advantage, which would become clear if we consider the model as depicted in Text-figure 1b where there is no intermediate language. If we are dealing with n different languages, we need $(n-1)$ translation programs for each language in the model shown in Text-figure 1b. We need a total of $n(n-1)$ translation programs. On the other hand, the model shown in Text-figure 1a requires only 2 n translation programs.

Fortunately, this first paper from the US on the use of Sanskrit for machine translation generated a lot of interest in India that three conferences have already been organised on using Sanskrit for computer applications. One of the most exciting applications is the use of Sanskrit as a natural language interface for computers. When compared to English, Sanskrit has many advantages for computer processing. This is due to the structural properties of Sanskrit. For example, Sanskrit is free from word ordering whereas English is not. The following Sanskrit sentences mean only one thing irrespective of the order in which the words appear.

रामः पुस्तकं पठति
पुस्तकं रामः पठति
पुस्तकं पठति रामः
पठति पुस्तकं रामः
पठति रामः पुस्तकं
रामः पठति पुस्तकं

Whereas, if the words are interchanged in the English sentence **Rama reads a book,** the meaning changes completely. This one property of Sanskrit alone leads to tremendous simplication in computer processing. There are also other properties of Sanskrit that make it suitable for computer processing. These include limited roots (about 4000) from which all words are formed in Sanskrit and well defined grammatic rules. Thus, it appears to me that it would make a lot of sense for an Institute like yours to dig into the past knowledge of this country to find clues to answers for many of the questions that you are searching answers for.

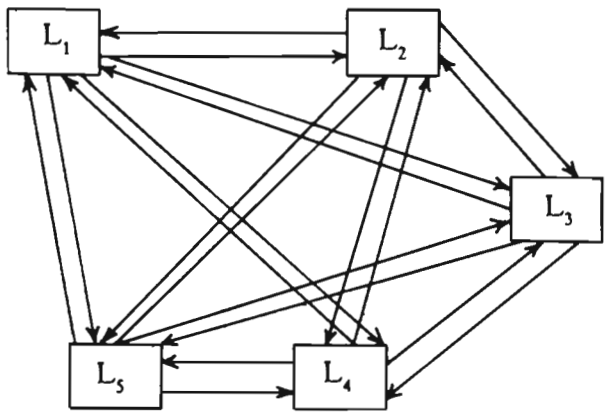
Let me now give you a perspective of the current status of the field of information. All of us know that information is important these days. The buzz phrases like 'Information is Power' and 'Information is the key to success' have become a reality. In fact, in the context of economic liberalisation and globalisation of markets, information has assumed even more importance. It is now clear that in order to stay competitive a company or for that matter even a scientist needs to gather, process and assimilate relevant information within a short time. This market demand for information is pushing up the price of information day by day. And, information has come to stay as a commodity with high inflationary trends.

One may attribute three important characteristics to the information scenario at present :

- Information Flood
- Information Drought
- Information Interdiscipline

The volume of production of information has more than doubled in the last decade. There is so much of information that is produced so fast these days that it is becoming humanly impossible to keep track of relevant information in a given field. To illustrate the kind of flood we are witnessing, let me give some statistics about the journals and articles published in the field of

Text-figure 1a—Intermediary based translation model.



Text-figure 1b—Direct translation model.

Science and Technology. There are about 6 million scientific articles published every year in about 60,000 journals. One can well imagine the intensity of flood if one takes into account newspapers and other popular science articles as well. There has been a ten-fold increase in the rate of publication in the last four decades. Certainly, human capacity to assimilate knowledge from these publications has not increased commensurately. So the question arises : how do we 'swim' through this 'flood'?

While there is a flood of information on the one hand, there is a serious drought of information on the other hand. The drought arises because of the inability of certain sections of the humanity to get access to information. The accessibility is restricted because of the expenses involved. As an example, India was receiving about 20,000 foreign periodicals in 1980 and in 1993, the number has come down to under 11,000. The rising cost of publications, the adverse exchange rate of Rupee to other foreign currencies, and the static or decreasing library budgets have contributed to this declining information resource in our country. The situation is no different in most of the other developing countries. So the question arises : how do we 'survive' this 'drought'?

Finally, our research is turning out to be more and more interdisciplinary in nature. For example, even in Palaeobotany an interdisciplinary approach is required in the context of DNA studies. We are at a stage where research in one discipline needs to draw upon information from other disciplines as well as make a contribution to other branches. The compartments that were erected between major sciences are crumbling today and there is a free flow of ideas among different disciplines.

Let me now illustrate the interdisciplinary nature of research by examples where information was sought from INSDOC. In one case, information was required on *instruments to scare away birds from airports*. Where do we search for such information; in publications relating to birds, instruments or airports? In fact, INSDOC drew more or less a blank from all these areas and could locate some information by searching literature on environment and air accidents.

The second example that I would like to quote is about *modelling of neural networks using biosensors*. Here, the area of search should include artificial intelligence, networks, mathematical modelling, network simulation, computer science, biology, neuro-science, etc. Clearly, research in any water-tight compartment can not take one very far. So the question arises : how do we organise information search across disciplines ?

Thus, the present information scenario raises three issues. Interestingly, all these issues can be resolved by application of information technology. The developments in the field of information technology permit efficient handling of massive data, networking of information bases, and computer based search of information cutting across different disciplines. The last aspect falls under broad subject of text retrieval systems.

Electronic databases and electronic publishing techniques permit us to handle large volume of information on computers. The number of electronic databases has increased ten fold in the last decade as shown in Table 1 and the number entries added per year has gone up by 20 times.

Table 1—Electronic databases

Number	1980	1992
Number of Databases	400	5500
Number of Database Producers	220	2000
Number of entries added per year	1 million	20 million
Online Services	80	800

Electronic databases are made available through on-line computer systems which can be accessed directly by using a personal computer and a modem via a telephone line. There are about 400 million telephone connections world over. Since the telephone network is widely prevalent, accessing on-line databases is technically feasible from almost any part of the world. Use of a telephone line is often expensive as the cost is directly proportional to the time of holding of the line rather than the volume of data searched and retrieved. The cost can be prohibitive enough to discourage the use of this mechanism particularly by the developing countries. Data networks permit search and retrieval in an efficient manner with the cost being proportional to the volume of data handled. Thus data network is a cost effective solution for searching on-line databases.

There are about 130 data networks world over of which four or five are in India. The notable ones among those in India are the Education and Research Network (ERNET), set up and managed by the Department of Electronics; Scientific and Industrial Research Network (SIRNET), set up and managed by INSDOC on behalf of CSIR; National Informatics Centre Network (NICNET), set up and managed by National Informatics Centre; INDONET, set up and managed by CMC Limited; and INET, which is a public data network, set up and managed by the Department of Telecommunications (DOT). ERNET and SIRNET function in a similar way and share their resources wherever possible. Both have international connectivity to all other networks. Both these networks are academic in nature and most of the academic, R & D institutions in India are connected to one of these two networks. As of November 1993, ERNET has about 210 nodes and SIRNET about 80 nodes. Most of the data networks provide electronic mail and file

transfer services predominantly. Some networks support other network services like **remote log in** and search and retrieval of databases. The transfer of full text documents consisting of pictures, figures, diagrams, graphs, etc. has not yet become common place.

In addition to the above wide area networks, Library Networks for resource sharing are being evolved in major cities of India. Among these are, Calcutta Library Network (CALIBNET); Delhi Library Network (PUNENET); and Bombay Library Network (Bonet). Of these, DELNET, MALIBNET and BONET are already operational. CALIBNET, the first library network to have been initiated in the country in 1986, is yet to become operational.

The most important advantage of library networks is that the participating libraries get immediate access to a large volume of information when compared to their own holding. Secondly, the library budgets can be effectively utilised to cut down the redundant acquisitions and to enrich the overall information resource. Viewing library networking as a measure for reducing the library budget goes against the objective of creating a larger and valuable information resource for the community of libraries in the network.

Text retrieval is a new area of research. The retrieval efficiency is normally gauged by two parameters : **recall** and **Precision.** Recall is the ratio of number of references retrieved from a database to the actual number of related references available in the database. Precision is the ratio of the number of relevant references retrieved to the total number of references retrieved. The most common mode of searching databases in vogue at present is through subject key-words. While key-word search gives a reasonable recall value, it often fails to give satisfactory precision. For example, I once carried out a search on the subject **computer audit** by using the key-words computer and audit. I got quite a few references in the topic of computer processing of auditory signals as the two key-words match this subject also. The precision in this case was perhaps less than 0.4. Nevertheless, key-word search is the most popular form of text retrieval mechanism in use at present all over the world. Realising the inefficiency of key-word based search, new techniques are being developed. They include :

1. Hypertext
2. Hypermedia
3. Knowbot
4. Virtual Reality

Hypertext is a technique where the related references are linked internally in the database by an information/ subject specialist at the time of creating the database or adding new entries. As a result, if the searcher is able to obtain one proper reference, he will be able to retrieve all the related references. Obviously, hypertext provides much better precision than keyword search. Hypermedia is an extension of hypertext technique to cover multimedia information like text, voice and video. Knowbot is a concept similar to that of the robot. The robot is designed to assist the human being in mechanical activities. A Knowbot is designed to assist the human being in the intellectual activities. In fact, a knowbot is expected to behave like an intelligent information assistant to a human being. Virtual Reality is a futuristic concept where a full scale simulation of events of the past and future can be constructed. Such a technique can be used to search information based on semantic requirements.

The techniques of Knowbot and Virtual Reality are becoming essential because a few decades ago, "*Computers promised a fountain of Wisdom but delivered a flood of information*". Search outputs based on key-words often deliver an enormous amount of information. It is becoming difficult for a human being to cope up with such large volume of information. Knowbots and Virtual Reality techniques are expected to reduce this large volume of information to meaningful wisdom. Having said about the trends in text retrieval, I must emphasise that in India, we only have key-word based search softwares, although in some parts of the world, hypertext and hypermedia are being experimented with.

Being an information scientist, I must effectively use information systems and I do this to the extent possible. For example, in order to prepare for this lecture and understand a bit about palaeobotany as well as Birbal Sahni Institute of Palaeobotany, I searched one of our databases using the key-word Palaeobotany. I was very happy to retrieve as many as 56 references out of which about 10 of them are very useful for the present purpose. I am giving in the Appendix-I a list of references retrieved from the database. In fact, if I had used terms related to Palaeobotany also as key-words, the number of references would have run into hundreds. The interesting aspect is that I could obtain these references in about two hours. I then availed the photocopy supply service of INSDOC and obtained copies of about six articles within two or three days. I have given this example to show how information technology can assist in obtaining quick and relevant information.

Let me now turn to trends in information services. The present information products and services are expensive and most often do not meet the specific needs of the end user. There is a need to search for new paradigms for information products and services so that the end users can easily afford them and get 100 per cent satisfaction out of them. In this context, information services are growing in two different directions :

1. Personalised Information Services (PIS)
2. Corporate Information Services (CIS)

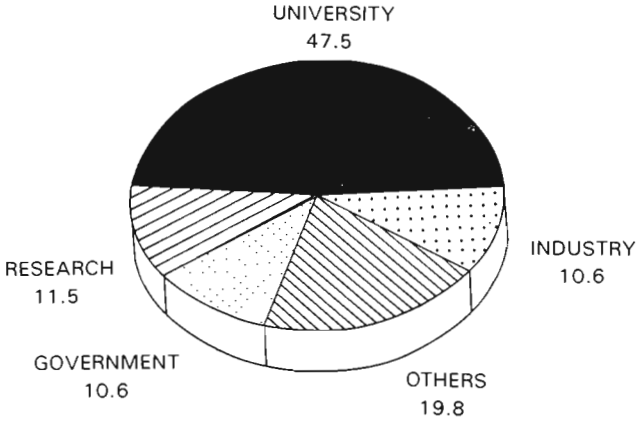
PIS and CIS are two paradigms for future information services. I would now like to illustrate these paradigms by taking example services from INSDOC. INSDOC offers a service called **Contents, Abstracts and Photocopies Service (CAPS)**, which falls in the category of PIS. Under this service, a subscriber can get the contents information from 40 journals of his/her choice selected from about 5000 core Indian and foreign periodicals. Firstly, such a service caters to the interdisciplinary requirements of the present day researchers. Secondly, it is totally personalised as no two subscribers may need the same set of journals. Thirdly, as only the relevant journals are covered, the cost is kept at an affordable level for an individual subscriber or a library. After browsing through the contents, a subscriber can order obstructs or photocopies of full text of articles at extra cost. An institution, corporate entity or individual can take more than one subscription in order to get access to make than 40 journals. On an analysis of about 300 subscriptions, we note that no two subscribers have chosen an identical set of journals. Clearly, this points to the fact that information requirements are highly individualised or personalised.

INSDOC launched its CAPS in late 1992. INSDOC set out with an objective of enlisting of about 1000 subscriptions in about two years and reach a level of 20,000 customers in a period of about six years. The marketing has been largely based on direct mailing. I am happy to say that the end of about one year, we have over 400 subscriptions for this service. We may only achieve 80 per cent of the target in the first two years but given the fact that the marketing has not been aggressive, we feel that this performance is satisfactory.

The current indications are that the CAP services have been very well received. It is indicated by the fact that out of about 150 subscriptions that became due for renewal, only eight of them did not renew the subscription and even they had stated that they have been very satisfied about the services but are not renewing for reasons not related to service satisfaction. Only one of the eight customers who was subscribing for information on floppies said that in the absence of an access software, it has not been possible for him to use this information effectively. INSDOC has since developed an access software for those who subscribe to the service on floppies.

CAPS is available in four different media : paper, diskette, email and fax. At present, the paper is being preferred dominantly, 87 per cent of the subscriptions are in paper medium. This is followed by diskette and a few subscriptions on email and fax.

The subscriptions are predominantly coming from universities followed by research institutions, industry and government. The universities contribute 47.5 per cent of the subscriptions and the three others are being very close to each other between 10 and 12 per cent each. Text-figure 2 gives the category-wise analysis of CAPS customers:



Text-figure 2—CAPS subscriptions analysis category-wise.

A discipline-wise analysis of CAPS subscriptions indicates that the maximum demands of CAPS originates in Life Sciences. This is followed by Engineering Sciences and Chemical Sciences in that order. Discipline-wise break-up of CAPS demand is given in Table 2.

Table 2—Number of journals in demand discipline-wise

Discipline	Percentage Demand (%)
Agricultural Sciences	7
Chemical Sciences	14
Computer Science and Information Technology	4
Engineering Sciences	19
Information Science	5
Life Sciences (Biological, Medical, Veterinary, Medicine and Animal Health)	41
Physical Sciences	10

The general philosophy of PIS is that an end user should be able to pin-point information of his requirement and pay only for that piece of information and not for anything extra. INSDOC is planning to introduce additional services in the PIS category in the coming year.

Corporate information services stem from the fact that many corporate entities find it difficult to maintain their own information system (IS) infrastructure and manpower. As a result, there is a trend on the part of the corporate entities to off-load IS activities to specialist organisations. Organisation like INSDOC now can maintain libraries in their own premises on behalf of a corporate entity and also run libraries belonging to corporate entities on a contract basis. Such services would start appearing in the coming

year. Time will tell how successful this paradigm would be.

In conclusion, the present information scenario is a mixed one of 'flood' and 'drought'. New paradigms are emerging for information services. Scientists must keep in mind these new paradigms and plan their information requirements accordingly. Research is becoming interdisciplinary in nature. Information technology offers efficient means of obtaining the required information cutting across disciplines. The scientists must learn to use information technology effectively to aid their scientific inquiry.

Appendix-I

CDROM SEARCH ON "PALAEOBOTANY" (1980-1993)* *excluding 1987

(SOURCE SCIENCE CITATION INDEX)

Allen K 1984. Paleobotany and the evolution of plants. Stewart WN (Editor)—*Nature* **308**(5955) : 125-125.

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Clemente westerhof JA 1984. Aspects of Permian paleobotany and palynology-4. The conifer *Ortiseia* Florin from the Val Gardena Formation of the dolomites and the Vicentinian Alps (Italy) with special reference to a revised concept of the Walchiaceae (Göppert) Schimper. *Rev. Palaeobot. Palynol.* **41**(1-2) : 51-166.

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Graham A 1988. Studies in neotropical paleobotany-6. The Lower Miocene communities of Paname—The Culebra Formation. *Ann. Mo. bot. Gdn* **75**(4) : 1467-1479.

Graham A 1989. Studies in neotropical paleobotany-7. The Lower Miocene communities of Paname—The Culebra Formation. *Ann. Mo. bot. Gdn* **76**(1) : 50-66.

Graham A 1991. Studies in neotropical paleobotany-8. The Lower Miocene communities of Paname—The Culebra Formation. *Ann. Mo. bot. Gdn* **78**(1) : 190-200.

Graham A 1991. Studies in neotropical paleobotany-9. The Lower Miocene communities of Paname—The Culebra Formation. *Ann. Mo. bot. Gdn* **78**(1) : 201-223.

Graham A 1991. Studies in neotropical paleobotany-10. The Pliocene communities of Panama—composition, numerical representations and paleocommunity paleoenvironmental reconstruction. *Ann. Mo. bot. Gdn* **78**(2) : 465-475.

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