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ABSTRACT

Experimentation and analysis dominate the activities with the Intrex information storage and retrieval system. Detailed analysis of the retrieval effectiveness of the Intrex-System configuration have been made in an effort to establish, quantitatively, the value of free-vocabulary and deep subject indexing; the usefulness of various fields of information such as title, abstract, subject-index phrases and so forth as indicators of desired information; and kinds of retrieval strategies that yield most complete and satisfying results. An experiment with the Massachusetts Institute of Technology (M.I.T.) compatible time-sharing computer in which a cluster of users simultaneously engaged the machine for information-retrieval purposes yielded valuable information for future designers of time-sharing systems dedicated exclusively to information retrieval. Details of this experiment are presented in Section B of this report. A thesis on Digital Communication Networks for Information Storage and Retrieval Systems has been presented by Mr. H. V. Jesse in satisfaction of requirements for his Electrical Engineer degree. His results are summarized in Section F. A detailed analysis of the performance reliability of the Intrex full-text storage and retrieval system has been made. The salient points of the study are discussed in Section G. (Author/NH)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT INTREX

SEMIANNUAL ACTIVITY REPORT

15 March 1972 - 15 September 1972

Intrex PR-14

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CAMBRIDGE MASSACHUSETTS

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PROJECT INTREX

Activity Report

I. INTRODUCTION

One of the early visions of the role of technology in the library of the future was recorded by John G. Kemeny at the M.I.T. Centennial in 1961.[1] In the decade that has passed since the publication of that landmark paper, Professor Kemeny has become President of Dartmouth College, and Dartmouth has moved into a leadership position in the use of interactive computing in undergraduate education. Last year, President Nixon appointed Dr. Kemeny to membership on the National Commission on Libraries and Information Science. The vision of the library of the future has not faded: In April 1972, Dr. Kemeny published a new paper[2] in which the updated concept of a national automated reference library is eloquently put forward.

The central reference library proposed in Dr. Kemeny's paper would make it possible for thousands of participating libraries to obtain any desired book easily, rapidly, and inexpensively. The individual participating library could thus limit the scope of its own collection to items that are in frequent demand by its own user community, and to books with which users wish to have immediate physical contact. The central reference library would provide everything else. While its operation would be expensive, its budget would be small compared with the total savings realized by the participating libraries.

The technical problems of such a plan are discussed by Dr. Kemeny under the three headings of storage, search, and transmission. After discussing the merits of microform and videotape, and the problems of mechanical selection, Dr. Kemeny concludes that the storage and rapid retrieval of the vast holdings of the central reference library will be entirely feasible.

The catalog for this large central collection would be computer-stored, and the user would interrogate it from interactive terminals. The dialog would

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1 John G. Kemeny, "A Library for 2000 A.D.", in Management and the Computer of the Future, ed. Martin Greenberger, Cambridge, Mass., and New York, N.Y., 1962, pp. 134-178.

2 John G. Kemeny, "Library of the Future", April 1972 issue of the Dartmouth College Library Bulletin. Also a chapter in a forthcoming book by John G. Kemeny, Man and the Computer: A New Symbiosis, to be published in the fall of 1972 by Charles Scribner's Sons, New York, N.Y.

rapidly narrow down the search to a small number of relevant items, for which abstracts would be displayed.

Remote access to the full text of the materials identified by the search would be provided by video transmission. At the receiving terminal, the pages would be displayed on a television-like screen or recorded on a copy-medium. If the latter route is chosen, on-demand printing at library terminals might eventually supersede conventional publication of scholarly materials.

The technology involved in Dr. Kemeny's plan has advanced rapidly in the decade between his two publications. During the past seven years, Project Intrex has participated in its development. We have put into operation an experimental information system which includes all the essential features contemplated by Dr. Kemeny in the service pattern of the National Automated Reference Library. The model has been on a reduced scale, to be sure, — not quite 20,000 documents —, but it was large enough to be of substantive interest to users in its fields of specialization. In experiments with users in all academic categories, we have demonstrated the feasibility and the effectiveness of interactive subject searches in a computer-stored catalog. We have provided, at the same library terminal, immediate access to full text by video transmission from a remote microfiche store. We have shown the feasibility of recording the full-text transmission on microfilm at the receiving site, and of producing enlarged paper copies on demand. We have designed and tested new user aids to help the reader in the transition from conventional to machine-aided library operation. There is no question of the technical feasibility of Dr. Kemeny's plan.

The objectives of Project Intrex have been reached. In building and operating the experimental system, and in observing and analyzing the users' interactions with that system, we have provided a foundation of factual knowledge for the design of such comprehensive information systems as the National Automated Reference Library or the mission-oriented systems that are needed for such major national tasks as the energy program.

Our program has been recorded in a series of semiannual activity reports of which this is the fourteenth, and the last to be issued by Project Intrex. The M.I.T. program in information transfer technology is now turning from Project Intrex to new tasks, initially in the area of network integration of disparate information systems.

Carl F. J. Overhage
Cambridge, Massachusetts
15 September 1972

II RESEARCH AND DEVELOPMENT PROGRAM (Electronic Systems Laboratory)

A. STATUS OF THE PROGRAM

Professor J.F. Reintjes

Experimentation and analysis have continued to dominate our activities with the Intrex information storage and retrieval system. Detailed analyses of the retrieval effectiveness of the Intrex-System configuration have been made in an effort to establish, quantitatively, the value of free-vocabulary and deep subject indexing, the usefulness of various fields of information such as title, abstract, subject-index phrases and so forth as indicators of desired information, and kinds of retrieval strategies that yield most complete and satisfying results. Contributing raw data to our analytic studies was an experiment conducted at the Rutgers University Graduate School of Library Service. Several Rutgers graduate students participated in the experiment via telephone communications established between a console located at Rutgers and the time-sharing computer at Cambridge.

An experiment with the M.I.T. compatible time-sharing computer in which a cluster of users simultaneously engaged the machine for information-retrieval purposes yielded valuable information for future designers of time-sharing systems dedicated exclusively to information retrieval. Details of this experiment are presented in Section B of this report.

A thesis on Digital Communication Networks for Information Storage and Retrieval Systems has been presented by Mr. H. V. Jesse in satisfaction of requirements for his Electrical Engineer degree. His results are summarized in Section F.

A detailed analysis of the performance reliability of the Intrex full-text storage and retrieval system has been made. The salient points of the study are discussed in Section G.

B. SYSTEM USAGE: EXPERIMENTS AND ANALYSIS

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SUMMARY

Use of Intrex facilities in the open environment has been further studied with special emphasis on search strategies employed by repeat users. The second series of catalog indicativity experiments has been completed on 20 experimental subjects with results permitting statistically significant statements about the relative values of several different catalog fields. Several additional retrieval-effectiveness studies have been completed with additional results relating retrieval effectiveness, indexing, and search strategy. An experiment was performed to test the capacity of the M.I.T. Compatible Time-Sharing Computer in terms of average response time as a function of number of online information-retrieval users in different contexts.

INTREX FACILITIES IN OPEN ENVIRONMENTS

At the end of its second year of regularly scheduled operations in the open environment, the Intrex Retrieval System had served more than eleven hundred different users of whom approximately 100 were added during the spring term. User reaction during this period was, on the whole, enthusiastic and the end of the Spring Term again saw the system in heavy use. Users at the Barker Engineering Library station often had to wait their turn even though there were three consoles available.

Heavy use is evidence of the system's growing acceptance by, and utility to, users. Other evidence of favorable user reaction includes the comments users write in the notebooks made available to them for that purpose near the consoles and the fact that the average user has engaged the system approximately twice. Repeated use suggests that there is more involved than a novelty factor.

User Experience and Changes in User Behavior. The behavior of users who made more than one use of the system was studied to determine the effects of familiarity with the system on user behavior. Our main reason for looking into

this matter was to see if we could extrapolate our observations in the current environment, while computer based information retrieval is still a novelty, to the day when it would be commonplace. We find the following changes as the user grows more familiar with the system:

1. The typical user makes greater use of the variety of features available in the Intrex system during his first session than he does in his subsequent sessions. He seems to settle on a particular strategy that suits his needs and uses that strategy, to the exclusion of others, in the second, and subsequent, sessions.

2. However, the typical user also seems to be more efficient in his use of the smaller set of techniques in his second and later sessions than he does during his first session. In particular, he spends a larger portion of his time looking at the data from the catalog.

3. Although individual users settle on relatively limited strategies after their first introductory or learning sessions, most of the various Intrex system capabilities are used in one or more of these particularized strategies and so there is little possibility of reducing over-all system capabilities significantly without also curtailing user-preferred strategies.

4. Users settle on limited strategies despite having been introduced to a fairly broad spectrum of system capabilities in the first session. These limited strategies are found to be far more optimal in their effectiveness. When users are shown, through forced intervention by an advisor, how better strategies — for example, the use of Boolean combinations or output of matching subject expressions — can improve search effectiveness, they readily adapt them to their own use. The conclusion is that, with present instructional techniques, users do not, in their early system use, easily perceive the utility of various sophisticated strategies. Furthermore, choosing the path of minimum effort, they do not seek to improve their strategies by taking advantage of the several means available to them to learn — as by reading the instructional guides, consulting human advisors, or experimentation. This, in turn, suggests the need for continuing programs of instruction which, in some sense, are forced on the user rather than being purely optional.

It is important to note that one mode of increasing sophistication is <u>not</u> measured by the simple counting techniques of this experiment. That mode has to do with the understanding of, and ability to search on, the deep, free-vocabulary indexing of Intrex. We have some indication that Intrex users do improve in this respect as their system usage increases despite the stability of their strategy development in other respects.

These conclusions are based on a study of the behavior of a sample of 30 users who came to the system at least twice. Five of these users came to the system more than twice and we were thus able to compare the changes from the first to second session with the changes from the second to the third. We found, in general, that things settle down by the second session in that little change from the second session to the third is evident. This suggests that the behavior in the second session may provide a reasonable basis for extrapolation of typical system usage when the system becomes familiar to the user.

The monitor-file records of the 30 users who used the system more than once were examined. The results of this examination are summarized in Table IIB-1

Table IIB-1

Changes from First to Second Session (30 Users)

Feature of Behavior	Median		Predominant Direction (*)
	First Session	Second Session	
Number of commands issued	27	20	Down (22/30)
Types of commands issued**	7	5	Down (27/30)
Number of documents for which some catalog information was examined	10	12	Up (16/30)
Number of field types looked at (i.e., number of distinct output command arguments)	4	2	Down (26/30)
CPU (computer time) used	4 min.	3 min.	Down (18/30)
CPU-to-Real-Time ratio	1/20	1/15	Up (25/30)

* Fractions indicate the fraction of the 30 users whose behavior changed in the direction indicated.

** Repeated uses of the same command (e.g., two or three subject searches) count as one command type here but as several commands in the preceding category (number of commands issued).

The changes from the second to the third session are summarized in Table IIB-2. Note that both the medians and the predominant directions show little change from second to third session.

The ranges that the variables shown in these tables take are also of interest. The largest number of commands issued in a first session was 80 and the smallest was six. In the second session the range was from 48 commands to five. The types

of commands used ranged from a high of 14 to a low of three in the first sessions and from seven to two in the second. (As before, login, logout, and begin commands were not included in these counts.) The number of distinct fields examined ranged from 11 to one in the first session but only seven to one in the second. The real-to-CPU

Table IIB-2

Changes from Second to Third Session (5 Users)

Feature of Behavior	Median		Predominant Direction(*)	
	Second Session	Third Session		
Number of commands issued	10	13	Up	(3/5)
Types of commands issued	3	3	Down	(3/5)
Number of documents for which some catalog information was examined	12	10	Up	(3/5)
Number of field types looked at	2	2	Even	
CPU time used	2 min.	2 min.	Up	(3/5)
CPU-to-real-time ratio	1/12	1/10	Down	(3/5)

time ratios ranged from 42/1 to 9/1 in the first, and 82/1 to 9/1 in the second. However, users looked at more documents in the second session. The high was 400 documents in the second and 211 in the first.

In summary, we find that user behavior seems to be more exploratory in the first session and more efficient in the utilization of time and effort in subsequent ones. These results will be documented in more detail in future reports.

CATALOG INDICATIVITY EXPERIMENT

The second series (series B) of the indicativity experiments has been completed. The results obtained from 20 experimental subjects each making 5 catalog field judgements on each of 20 documents allow us to make statistically significant statements about the value and role of different kinds of catalog information in the evaluation of documents by users.

Indicativity is a measure of the accuracy with which a user can judge the value of a document on the basis of catalog information. It is computed by comparing the value judgement a user makes on the basis of a given type of catalog information (e.g., title or abstract) with the value judgement that the same user makes on the basis of the full text. If the judgements tend to be the same, the

indicativity of that type of information is high. To the degree that the judgements differ, the indicativity of that given kind of information is diminished.

Indicativity thus serves to measure the utility of the catalog information in one of its two major roles — those of evaluating documents to decide if the text of the document is worth obtaining and of providing the basis for searching. The latter role is measured by retrieval effectiveness, discussed in the next section.

Indicativity and retrieval effectiveness, together, measure the benefits that accrue to the user from the inclusion of a field in the catalog. Taken with measures of the costs of such inclusions, they provide the basis on which a system designer can decide what information should, or should not, be included in a retrieval system.

The indicativity ratings of four of the major content-indicating fields are given in Table IIB-3 for both the series A and series B indicativity experiments.

Table IIB-3

Indicativity Results for Series A and Series B Experiments

Field	Indicativity		
	Series A (9 subjects) - %	Series B (20 subjects) - %	
		Raw	Adjusted*
Title	66	64	74
Matching Subject Expressions**	71	67	79
Subject Expressions	74	70	86
Abstract (or excerpt)	75	73	86

* Raw indicativity scores are adjusted after interviewing the experimental subject to exclude those failures in indicativity which reflect variations in evaluator judgments rather than lack of information in the given field.

** The matching subject expressions are the expressions in the subject field that match the search request in one or more words. In the Series A experiments these were presented with the title, author name and location in a journal. In Series B they were presented alone.

The data from the two series are quite consistent with each other, particularly with respect to the indicativity of fields relative to each other. Abstracts were more indicative than subject expressions, which, in turn, were more indicative than title. Not all the differences were of equal statistical significance. The significance levels at which one can assert these relative positions, as determined by the Wilcoxon matched-pairs signed-ranks tests, are given below:

Hypothesis	Significance Level
Abstracts more indicative than titles:	0.005
Subject expressions more indicative than titles:	0.005
Matches more indicative than titles:	0.025
Abstracts more indicative than matches:	0.025

Note that, although the differences in indicativity are relatively small, many of them are statistically significant at quite high levels. They are also more significant from a user's point of view than the numbers in the above table may suggest. Thus, the percentage of documents whose utility was judged incorrectly by title is 36 percent, whereas incorrect judgments by abstract are only 27 percent — an improvement of about 25 percent if one focuses on what might be lost to the user if he uses the title rather than the abstract. The improvement is even more noticeable for the adjusted indicativity, a user focusing on just the title misses 26 percent while the user who focuses on abstract or subjects misses only 14 percent, almost twice as good a performance.

In Series B, we also attempted to evaluate the utility of the other fields (kinds of catalog information) not covered above. To do this, we gave each user a list of the names of the 54 catalog fields, together with a brief description of the kinds of information those fields contained. We asked the user to indicate those fields he thought would be useful to him for the purpose of evaluating documents. The measure, based on the percentage of users who checked a field's description, is called the "preferability" of the field. Each subject was also given the full catalog record for three of the documents used in the indicativity experiment and asked to indicate which parts (fields) of the information that appeared in the record he would have considered helpful in making his judgments. The percentage of field occurrences for a given field (few fields occur in every document record) that were so indicated as actually helpful for making judgments is called the field's "utility". The preferability and utility ratings of the fields are given in Tables IIB-4 and IIB-5. Note the broad variety of fields that are considered useful and/or helpful by at least some users.

When asked their opinions of the four content-indicating fields, most of the experimental subjects (14 out of 20) expressed a preference for the abstract. Only one subject expressed a preference for the subject expressions (and one for the matching subject expressions) even though the subject expressions are about as indicative as the abstract. The reasons most frequencly cited for preferring the abstract was that it gave the most complete information in a comprehensive form (i.e., it was "readable") and that it gave the article's perspective on the subject matter.

Although subject expressions rank lower in indicativity than the abstracts, they rank higher in what we might call "reliability". In order to determine the

Table IIB-4

Preferability of Catalog Fields

Catalog Field and Field Number	Percentage of Users Checking the Field
Subject Index Expressions	100
Abstract (71), Excerpts (70), Title (24)	95
Text (90)	89
Matching Index Expressions (74)	74
Author's Purpose (65)	68
Author (21)	63
Table of Contents (67)	42
Language of Text (36)	37
Publication Date of Book or Report (29), Author's Affiliation (22), Language of Abstract (37), Level of Writing (66), Features (68)	32
Format (31, Bibliography (69)	26
Reference Citations (80), User Comments (85)	21
Reviews (72), Pagination (32), Normal (76)	16
Library Location (11), Main Entry (20, Coden (25), Medium (30), Thesis Statement (43), Journal Issue Citation for Articles (47)	11
Illustrations (33), Supplement (41), Serial Holdings (12), Corporate Author (23, Publisher (27), Series Statement (38), Contract Statement (40, Standard (75)	5

Table IIB-5

Utility of Catalog Fields

Catalog Field and Field Number	Number of Occurrences in Catalog Records	Percent of Occurrences Checked as Useful
Title (24), Abstract (71)	31, 53	100
Subject Index Expressions (73)	57	93
Table of Contents (67)	18	83
Excerpts (70)	3	67
Standard (75)	27	63
Author's Purpose (65)	57	42
Features (68)	19	37
Author (21)	30	30
Author's Affiliation (22)	55	24
Language of Text (36)	57	23
Language of Abstract (37)	49	16
Level of Writing (66)	57	11
Research Group for whom Acquired (2)	57	9
Bibliography (69)	54	7
Illustration (33)	56	5
Format (31)	57	2

reliability of the ES's value judgments, several fields for a document were presented twice and the judgments made at each presentation compared. The subject fields produced significantly less variable judgments than did the abstract. It should also be noted that our retrieval effectiveness studies have shown that retrieval on Intrex subject expressions is far superior to retrieval based solely on abstract words.

We used the data from Series B to evaluate the "Length Hypothesis", according to which the indicativity of a content-indicating catalog field is correlated (positively) with its length: the longer the field the greater the indicativity. This hypothesis is verified by our data most strongly if the length of a field is measured in terms of the number of word types or the number of content-word types and somewhat less strongly if the number of actual word occurrences (i.e., word tokens), counting each repetition as a different occurrence, is used. This seems reasonable on the grounds that repeated uses of the same word may not add as much information as uses of new words.

RETRIEVAL-EFFECTIVENESS EXPERIMENTS

The retrieval-effectiveness experiments are a series of tests and comparative studies designed to: (1) evaluate the retrieval performance of natural-vocabulary indexing with respect to depth of indexing; (2) evaluate the effects of coordination logic, word morphology and stems, and vocabulary exhaustivity on retrieval performance; (3) develop optimal strategies for searching with natural vocabulary; (4) compare retrieval performance with natural-vocabulary manual indexing to performance with controlled-vocabulary indexing and to performance with natural-vocabulary text; and (5) to develop a model based on the above experiments that identifies the factors affecting the interactive-retrieval performance of natural-vocabulary indexing, and the relative importance of those factors. Retrieval-effectiveness studies covering one or more of the above areas have been reported continuously in the Project's Semiannual Activity Reports dating from 15 March 1970.

Since the last report of 15 March 1972, we have completed an in-depth analysis of retrieval effectiveness for two additional cases drawn from the indicativity series of experiments, namely those for the search problems presented by experimental subjects ES 29 and ES 31. The major results obtained from these two cases are summarized briefly below. The general methodology for these particular studies was previously reported on pages 21-22 of the 15 March 1972 Intrex Activity Report.

Rutgers Experiment. A modified form of the retrieval-effectiveness methodology also served as the basis for the Intrex-Rutgers experiment described initially on page 19 in the last Semiannual Activity Report. That experiment was conducted on 1-6 March 1972 at the Rutgers University Graduate School of Library Service using a portable DATEL communications terminal and an acoustic coupler with ordinary dialed-telephone-line communication to the M.I.T.-modified 7094 (CTSS) computer in Cambridge. The experiment — which studied natural-vocabulary search strategy development, retrieval performance, and depth of indexing — utilized three new cases drawn from the indicativity series of experiments, namely those for the search problems presented by ES 32, ES 34, and ES 36.

Because the analysis of these three experimental cases has not yet been completed, we defer reporting further on this experiment to a future report. However, it is a pleasure to acknowledge at this time the cooperation and enthusiasm received from Dr. Susan Artandi and the 12 first-year doctoral candidates who participated in the formal experiment. In addition to that part of the cooperative effort in which the doctoral students themselves searched the Intrex data base using their own search strategies, demonstrations of the Intrex system were given to several dozen interested master's level students. We find it encouraging to report that Rutgers students and staff found the experiments and the live demonstrations on interactive, online retrieval systems a valuable educational experience.

Retrieval-Effectiveness Studies with Experimental Subject ES 29. The initial recall test base contains the ten documents rated relevant out of the 20 document texts examined by ES 29 in the indicativity experiments. A comparative analysis of Intrex indexing of those ten documents, together with a study of the elements of the ES's original written natural statement of his problem, led to the development of a hypothesized optimum compound search strategy for Intrex retrieval. The component themes and the Intrex logic and natural vocabulary for the overall search strategy are given in Table IIB-6.

The ES in his written statement indicated interest in the properties expressed by themes a, b, and c in the table in a "2024 aluminum alloy." His relevance judgments on the known recall set showed, however, that he was also interested in the other aluminum alloys as expressed in themes e and f above. The optimum strategy captured this expanded interest from the outset because it was developed from both the problem statement plus an examination of the indexing of known relevant documents (that is, some feedback was involved). The search-strategy vocabulary contains both the name and symbol of chemical elements. The several word forms representing the aging property reflect the way in which the Intrex word stemming algorithm works on stems of less than four characters.

Table IIB-6

Themes and Search-Strategy Components for ES 29

Theme	Vocabulary and Logic
a) age hardening	aging OR ageing OR aged
b) precipitation hardening	precipitation
c) Guinier Preston zones	Guinier Preston OR GP
d) aluminum alloys	aluminum OR aluminium OR Al
e) aluminum-copper alloys	copper OR Cu
f) aluminum-zinc alloys	zinc OR Zn
g) 2024 aluminum	2024
Optimum Strategy: (a OR b OR c) AND d AND (e OR f OR g)	(age OR ageing OR aged OR precipitation OR Guinier Prestion OR GP) AND (aluminum OR aluminium OR Al) AND (copper OR Cu OR zinc OR Zn OR 2024)

The optimum strategy retrieved in Intrex a list of 91 documents that included all ten initially known relevant documents (100 percent recall) and none of the ten initially known non-relevant documents (100 percent estimated precision). The full text for a sample of 30 of the 81 documents not previously seen by the ES were presented to him for relevance judgments; the ES subsequently also judged a second sample of 29 documents on the basis of their titles and matching Intrex index expressions. The ES rated as relevant, 21 (9 highly useful, 12 useful) of the 30 documents in the text-judged sample, and 17 (7 highly useful, 10 useful) of the 29 documents in the matching expression-judged sample. The true precision of the text sample is 70 percent and for the other sample it is 59 percent. While this difference is not statistically significant (as measured by the two-tail chi-square test at a 95 percent confidence level), it could conceivably be due to the failure of the user to recognize some documents as relevant on the basis of abbreviated information. Because full text is the ultimate basis for relevance judgments, we use the precision value for the text-judged sample and the 100 percent precision of the initial recall base to calculate a new estimated overall precision value for the optimum strategy as 73 percent. It was not possible to derive a value for the overall recall performance of the optimum strategy because ES 29's bibliography was not exhaustive and it did not contain documents that overlapped the Intrex data base.

On the basis of the relevance judgments and comments made by ES 29, an analysis was made of the contributions to retrieval performance of each of the components contained in the optimum strategy. ES 29 considers "age hardening" and "precipitation hardening" as synonymous for his purposes, although they are not true synonyms. ES 29 was clearly interested in alloy behavior and the mechanisms of that behavior as determined by precipitates. Although an aging process is involved, relevant documents almost always must contain some discussion from a precipitation viewpoint; few documents are relevant if they exclude that view. However, in terms of retrieval strategy, for example, if the various words expressing the aging theme are deleted, then the revised strategy would retrieve 69 documents with 81 percent precision, but recall of known relevant documents drops to 92 percent. If the word "hardening" were coordinated with the aging terms, then recall would improve, but only partially. These and other analyses led to the conclusion that the optimum strategy, as initially derived, was a satisfactory strategy that did not need further revision.

The recall effectiveness as a function of indexing depth for the optimum strategy and its components is presented in Figs. IIB-1 and IIB-2 for the 31 documents rated relevant on text. Cumulative recall is plotted against the cumulative number of unique word stems in the Intrex index expressions. The index range number corresponding to each point is shown, and the order is title (or range 5), followed by ranges 1, 2, 3, 4, and 0. The list sizes retrieved by each component are also shown. These curves again illustrate the importance to effective retrieval performance of the Intrex ranges 2 and 3 deep index expressions. In addition, there seems to be some further support for our "diminishing returns" model (see 15 March 1972 Semiannual Report, pages 29-40) in that those strategies with greater coordination of terms, as in the optimum strategy, generally resist the diminishing returns effect and show relatively greater return for increasing indexing depth than those strategy components made only by single terms or their disjunctions.

It is of interest to compare the optimum strategy performance achieved on Intrex indexing with the performance of the same strategy employed on text. This was done using the cumulative words appearing in the titles plus abstracts of the relevant documents. The results conform to results previously reported for other cases. Recall effectiveness of title plus abstract words is about as good as recall effectiveness from indexing to a depth of range 2 in Intrex. We note that the cumulative number of unique word stems through title plus abstract word depth is more than twice the number of such stems through the depth of range 2 in Intrex manual natural vocabulary indexing. This result again demonstrates the ability of a good manual indexer to select the most important words while leaving out words of less value for retrieval.

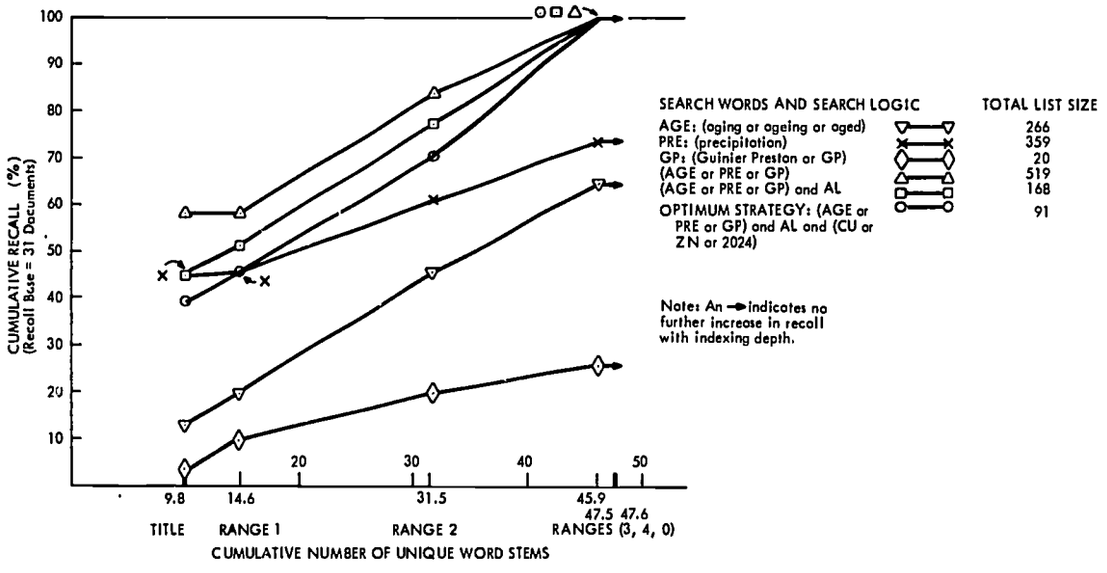

Fig. IIB-1 Cumulative Recall vs. Indexing Depth for 31 Text-Judged Documents Retrieved by the ES 29 Optimum Strategy or One of its Property Components

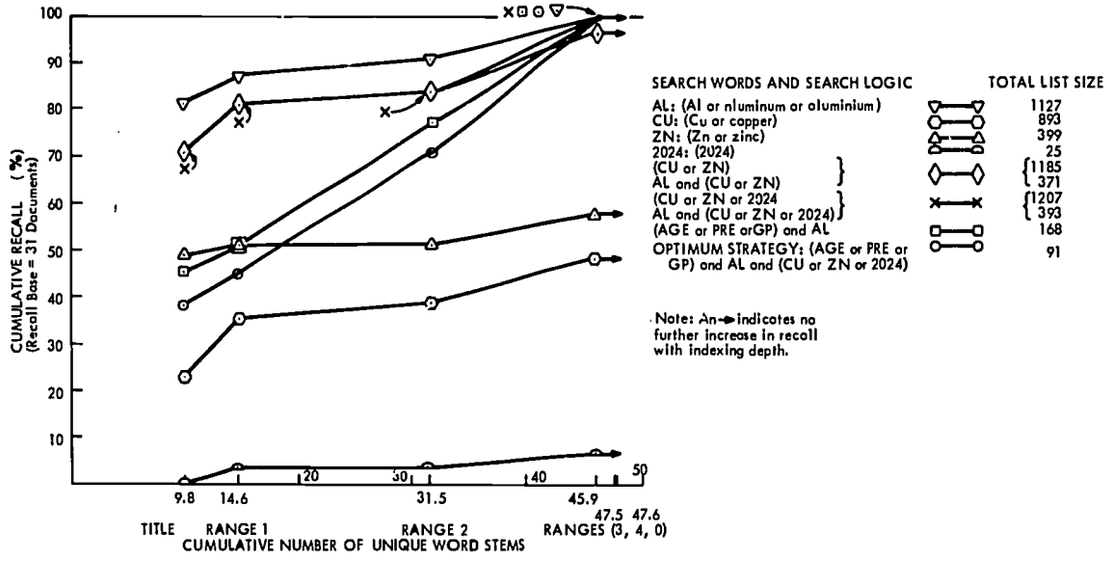

Fig. IIB-2 Cumulative Recall vs. Indexing Depth for 31 Text-Judged Documents Retrieved by the ES 29 Optimum Strategy or One of its Materials Components

The initial ten known relevant documents were all indexed by Metals Abstracts (MA) and the characteristics of the controlled indexing were determined for that set. Another analysis to determine which of these documents would be retrieved if the Intrex optimum strategy were applied to the index terms of Metals Abstracts (and assuming phrase decomposition of those headings) yielded the results shown in Table IIB-7.

Table IIB-7

Metals Abstracts Search Results for ES 29 Strategies

Search Strategy	Recall of 10 Known Relevant Documents (in Percent)
(aluminum OR aluminium OR Al)	100
(age OR aging OR aged OR precipitation OR Guinier Preston OR GP)	80
(copper OR Cu OR zinc OR Zn OR 2024)	0

It is worth noting that the 10 relevant documents were spread fairly equally among four different sections of the MA classification and so searching solely by classification terms would not have been very useful. Although in this analysis the number of known nonrelevant documents retrieved was not investigated and there was no conscious effort made to design an optimum strategy specifically for MA, there does, superficially at least, appear to be further confirmation of our previous results which indicate that the relatively shallow and nonspecific indexing of abstract journals (here evidenced by the failure to index the specific type of aluminum alloy) is greatly inferior to Intrex-type indexing for the typically specific problems of real searchers.

Retrieval Effectiveness Studies with Experimental Subject ES 31. The retrieval-effectiveness analysis for the ES 31 case followed the methodological lines previously discussed, but six strategies (labelled OPT 1 through OPT 6) evolved during the problem analysis as additional information became available with each successive strategy. In this discussion, we relate the differences in retrieval performance of the strategies to differences in vocabulary and search logic.

ES 31's problem statement on the dynamic properties of magnetoelasticity, especially those properties relating to microwave and optical interactions, contained several themes and was the most complex of the statements we have worked with to date.

Subsequent to the development of the first five initial strategies, further information was obtained from ES 31 in the form of a review paper published by him and which had prompted his original problem statement. The review paper contained a bibliography with 89 references, 41 of which were in the Intrex data base. These documents extended the recall base on which to test the relative performance of the strategies beyond the 11 known relevant documents from the 20 document indicativity experiment. As a result of these analyses, and also from a detailed analysis of the relationship of the thematic elements of the original problem statement to the elements in the resulting review paper, a sixth strategy was developed which contained an expanded vocabulary.

The major themes and the vocabulary and logic used to express them are listed in Table IIB-8.

Table IIB-8

Themes and Search Strategy Components for ES 31

Theme	Vocabulary and Logic
a) magnetoelasticity	a1) magnetoelastic OR magneto-elastic a2) magnetostriction OR magnetostatic
b) phonon-magnon interaction	b1) phonon WITH magnon b2) [(spin OR magnon) WITH (phonon OR elastic OR photon OR resonance OR relaxation OR instabilities OR instability OR conversion OR exchange)]
c) microwave	c) microwave
d) ferromagnets and antiferromagnets, especially YIG and $RbMnF_3$	d1) (ferromagnet OR antiferromagnet) OR (YIG OR yttrium iron garnet) OR (RbMnF*sub 3* OR rubidium manganese fluoride) d2) ferrimagnet OR ferrite
e) parallel pumping	e1) parallel WITH pump e2) (parallel OR photon) WITH pump
f) Bragg scattering	f1) Bragg-scattering f2) (Bragg OR light) WITH (scattering OR diffraction)

The six strategies successively developed using the code letters for the strategy components from the table were:

Strategy	Logic
OPT 1	[a1] AND [b1 OR c]
OPT 2	[a1 AND (b1 OR c)] OR [d1 AND (e1 OR f1)]
OPT 3	[a1 OR d1] AND [b1 OR c OR e1 OR f1]
OPT 4	[a1] AND [b1 OR c OR d1 OR e1 OR f1]
OPT 5	[a1 OR b1] AND [c OR d1 OR e1 OR f1]
OPT 6	[a1 OR a2 OR b2] AND [c OR d1 OR d2 OR e2 OR f2]

A sample of 69 documents representative of the six strategies and their major components, and not previously seen by ES 31, were presented to him for text-based relevance judgments. ES 31 rated 29 of the sample documents relevant. Thus, from the indicativity experiment, review paper bibliography, and the strategy retrieval sample, relevance judgments were available for 107 documents, 60 of which were relevant. The comparative retrieval performances of the six strategies are shown in Table IIB-9.

OPT 1, OPT 2, and OPT 3 have rather poor recall performance but good precision. OPT 4 and OPT 5 do much better on recall although the recall values are only moderate, and also, generally, better in precision. OPT 6 does considerably better than any other strategy on recall but with only moderate precision results. OPT 1 has a very limited vocabulary and a very restricted logic in that the magnetoelastic and phonon-magnon themes are ANDed. These two conjoined themes are actually somewhat synonymous for this problem. OPT 2 has additional vocabulary and it is formed by disjoining OPT 1 with another phrase that contains a single conjunction and whose structure is the same as that of OPT 1. OPT 3 has no new vocabulary over OPT 2 but does contain a change in conjunction logic: only one conjunction. OPT 4 has only a simple change in logic from OPT 3, and there is no change in vocabulary. OPT 4 retains the single conjunction, but now all of the disjunctions appear in only one of the conjoined phrases. It may be noted that OPT 4 has the same logic as OPT 1 but with an expanded vocabulary; the difference in recall performance of these strategies is striking. OPT 4 had the highest estimated precision of any strategy. OPT 5, which has the same vocabulary as OPT 4, represents a change in logic back to the structure of OPT 3 but now, the vocabulary disjoined has undergone a major change to reflect the synonymous-type relations between the magnetoelastic and phonon-magnon themes. OPT 6 has essentially the same logic as OPT 5, but it also has a greatly expanded vocabulary, giving it the highest recall performance.

These results indicate that the interplay between vocabulary and logic is a significant factor in retrieval effectiveness and that optimality cannot be achieved without considering both of these factors. In addition, these results demonstrate the importance of feedback and interaction in the development of optimal

Table IIB-9

Retrieval Effectiveness of Six Strategies for the ES 31 Problem with Respect to the Total Text-Judged Evaluation Base of 60 Relevant Documents and 47 Non-relevant Documents

Strategy	Number of Relevant Documents Retrieved	Number of Non-relevant Documents Retrieved	Recall	Estimated Precision	Total List Size
OPT 1	14	4	0.23	0.78	38
OPT 2	20	8	0.33	0.71	76
OPT 3	27	17	0.45	0.61	188
OPT 4	33	7	0.55	0.83	122
OPT 5	38	12	0.63	0.76	142
OPT 6	56	39	0.93	0.59	586

Note: The number of documents on which relevance judgments were made is less than the total number of documents retrieved by a strategy.

strategies. Strategies OPT 2 through OPT 5 were designed by the Intrex analysts by successively modifying preceding strategies in consequence of analyzing their results. Strategy OPT 6 was designed after feedback from the ES giving relevance judgments on results of the other strategies.

Distinctions among these strategies were also noted with respect to the differential recall of the 41 documents in ES 31's bibliography relative to the review paper sections — and hence the problem themes — which reference those documents. OPT 6 performed best and OPT 5 second best with respect to: (1) the percentage of bibliography references in each paper section retrieved; and (2) the balance of each strategy over the total problem as reflected by the distribution of documents retrieved over the various sections of the paper.

Taking these several factors into consideration, including the list sizes retrieved by each strategy, we conclude that OPT 6 is the best strategy for a user who wants a highly exhaustive exploration of the subject area of the review paper. However, for a search that need not be exhaustive, OPT 5 and OPT 4 both offer quite adequate performance values, both have list sizes that are not too large to scan through, and they retrieve documents reasonably balanced among the several themes of the paper. Because OPT 5 does perform slightly better than OPT 4, and its logic

better represents some synonymous relations, OPT 5 is considered the best overall strategy. In contrast, OPT1, OPT 2, and OPT 3 give poor overall performance.

At the time ES 31 made relevance judgments based on the text of samples drawn from the lists retrieved by the strategies, we discussed with him the meaning and relationships among various vocabulary words in these strategies. For example, magnetoelasticity and magnetostriction are terms used more or less interchangeably, although the problem statement contained only the former term. Further, although ES 31 was interested in ferromagnets, and in YIG in particular, YIG is a ferrimagnet which acts as a ferromagnet. We also discussed with him how accurately the original problem statement reflected the resulting review paper. His comments supported our previous comparative analysis of the statement and the paper. The original statement was, in general, a fair representation of the paper, although some topics in the paper were given only implicitly in the problem statement. However, the problem statement could have been qualified to exclude metals and to restrict itself to insulators. Many sample documents were rated not relevant because the magnetoelastic phenomenon was occurring in metals. However, other documents were rejected not because the materials studied, per se, were outside ES 31's area of interest, but because ES 31 also required these materials to have, in this application, a low-loss characteristic. Some documents rejected by the ES contained numerical results for loss which showed them to be inappropriate, whereas for some other documents, the ES had to make mental calculations which determined that the material was too lossy for his purposes. Some 35 percent of the 40 nonrelevant sample documents were rejected because the material used put the document outside ES 31's subject area; in ten cases this was because the material was metallic.

We simulated the effect of revising the materials aspects of the above strategies. If the logic phrase 'AND NOT (metal OR alloy OR alloys OR ion)' is added to theme (e1) above in strategies OPT 2 through OPT 5, and to (e1 or e2) in OPT 6, then recall decreases slightly (at most, by 0.05 for OPT 6), but precision is considerably enhanced for all strategies, as shown in Table IIB-10. Estimates for the total list size retrieved by these revised strategies are also given. The improvements resulting from the modification are further evidence of the need for, and utility of, interaction in search-strategy formulation.

The vocabulary and search logic for the individual themes of this complex problem contain a variety of situations illustrating when it is important to use or to ignore restrictive commands for natural-vocabulary searching. For example, the word "magnetoelasticity" appears in the literature as both one word and a hyphenated compound word. To retrieve documents indexed only by the latter form, extensive analysis shows that "magneto!-elastic" which contains an exact-word-form command as

well as a word-adjacency command (the ! and - commands, respectively), performs better than the less restrictive "magneto-elastic" which contains only the adjacency command. However, when this theme is coordinated with other themes relevant to the problem, the performance differences become negligible and, therefore, the less complex, less restrictive form of the expression is preferable in an optimum strategy. In another example, where we want to express the subject "phonon-magnon interactions"

Table IIB-10

Recall Effectiveness of Revised Optimum Strategies with Respect to the Total Text-Judged Evaluation Base of 60 Relevant Documents and 47 Nonrelevant Documents

Revised Strategy*	Number of Relevant Documents Retrieved	Number of Non-relevant Documents Retrieved	Recall	Estimated Precision	Estimated Revised List Size
OPT 1	14	4	0.23	0.78	38
OPT 2	19	2	0.32	0.90	52
OPT 3	26	9	0.43	0.74	150
OPT 4	31	2	0.52	0.94	93
OPT 5	36	6	0.60	0.86	112
OPT 6	53	26	0.88	0.67	475

*Strategies OPT 2 to OPT 6 include the phrase 'AND NOT [metal OR alloy OR alloys OR ion]' as part of the logic expressing the materials theme.

Note: The number of documents on which relevance judgments were made is less than the total number of documents retrieved by a strategy.

as a search phrase, analysis shows that for effective retrieval the two words should occur in the same index expression, but without the adjacency command which, in this case, is too restrictive; thus we use "phonon WITH magnon" and not "phonon-magnon".

The recall effectiveness of the six strategies and their components was studied as a function of indexing depth. Figure IIB-3 plots cumulative recall versus cumulative unique word stems for all six strategies. Ranges 4 and 0 did not contribute to recall. The most exhaustive strategy, OPT 6, performs better at all indexing levels. Note that the rate at which deeper indexing adds relevant documents in OPT 1, OPT 2, and OPT 3 increases with depth of indexing, whereas with OPT 4, OPT 5, and OPT 6 the rate decreases, that is, the curves for the last three strategies follow

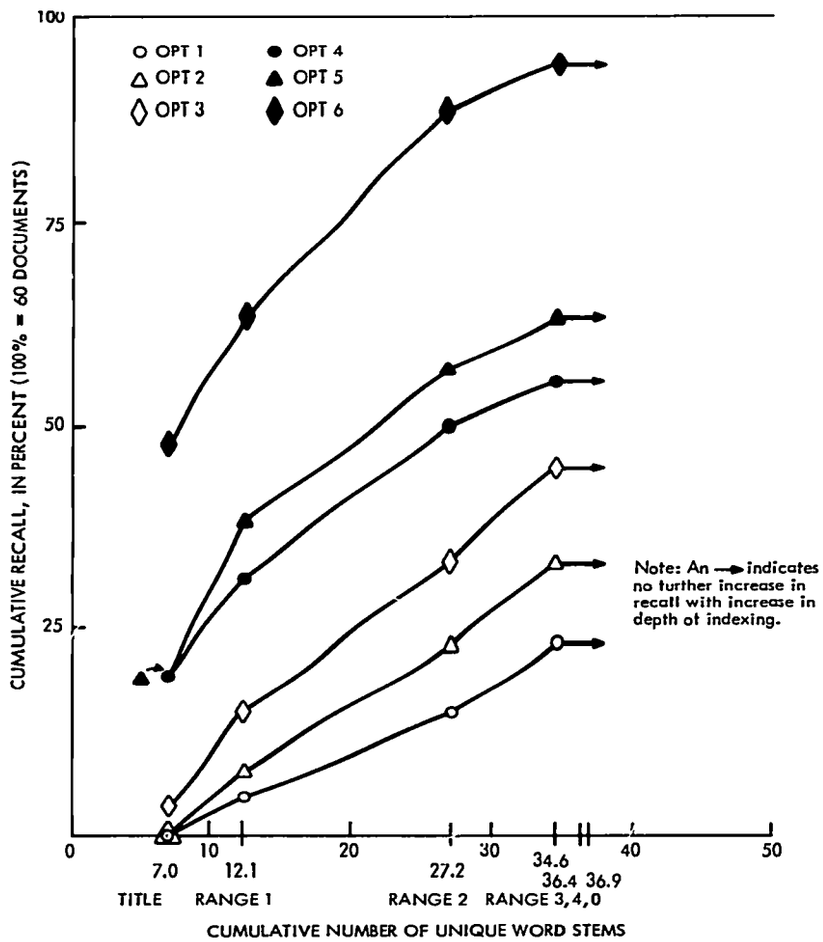

Fig IIB-3 Cumulative Recall vs. Depth of Indexing for the 60-Document Text Judged Recall Base (Numbered above 4000) for the six strategies developed for the ES 31 Problem

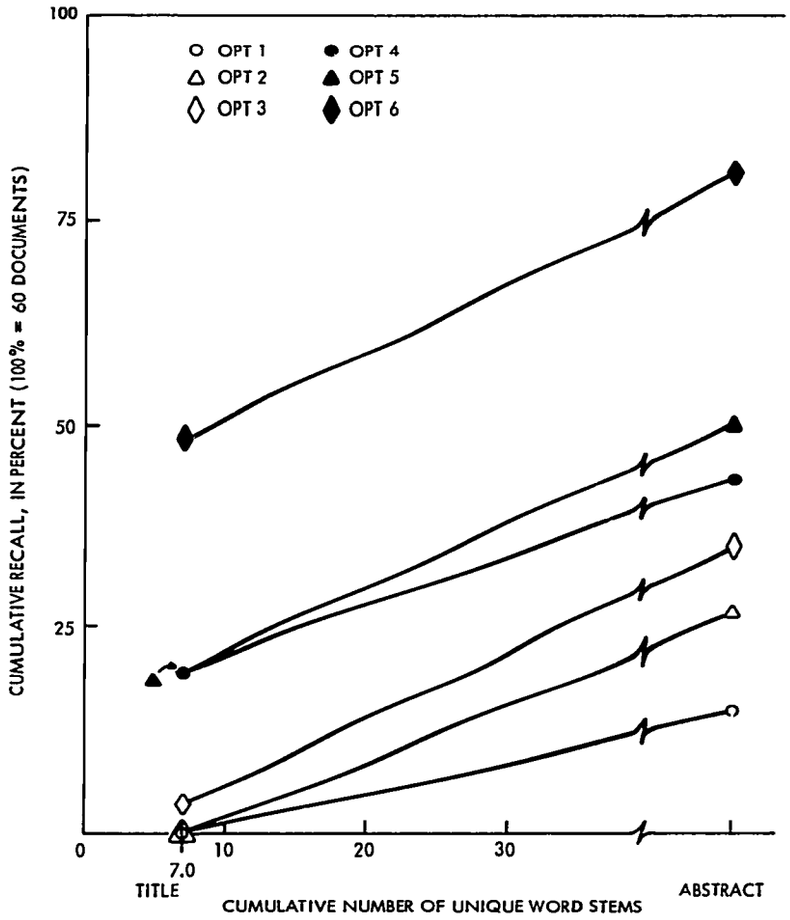

Fig IIB-4 Cumulative Recall vs Depth of Title and Abstract Text Words for 60-Document Text-Judged Recall Base for the six strategies developed for the ES 31 Problem

the law of diminishing returns. Documents retrieved by OPT 1, OPT 2, and OPT 3 have the least balance in their distribution over the themes of the problem and review paper. It may be, as we have discussed previously (Semiannual Activity Report, 15 March 1972, page 36), that strategies that either partially or poorly represent a problem, tend to retrieve documents that also are only partially about the problem, and hence the relevant indexing is at a deeper level.

Figure IIB-4 plots cumulative recall versus the cumulative words appearing in the titles plus abstracts of the relevant documents. Previous results show recall effectiveness of text through the depth of abstract words is about as good as recall effectiveness on indexing to a depth of range 2 in Intrex. These results are generally supported here, although in this case, and particularly for OPT 4, OPT 5, and OPT 6, the abstracts perform somewhat less well, that is, somewhere between range 1 and range 2 Intrex indexing.

TIME-SHARING-COMPUTER EXPERIMENT

Introduction. On February 24, 1972 Intrex scheduled a special test session for its host computer system, CTSS. The purpose of this test session was to evaluate the performance of CTSS as a dedicated information-retrieval computer by placing on the system a controlled load of information-retrieval activity produced by several persons simultaneously using the Intrex Retrieval Programs. The experiment involved the coordinated efforts of some 20 people operating in synchronism under a carefully controlled set of rules.

The experiment consisted of two parts. In Part I users were required to issue specific commands according to a predetermined schedule. In this way the computational load on the system could be carefully controlled and the system performance on tasks of known complexity could be studied under different loading conditions. In Part II users were requested to perform a search on an assigned topic using any techniques within Intrex that they might have at their disposal. Part II was intended to more closely simulate normal operational use of the system for information-retrieval purposes. The system load was controlled by allowing users to perform their searches only within a prespecified interval of time.

For the analysis of Part I, all instances of commands of similar computational complexity were identified and plotted on a graph of the number of active users versus response time for the command. The points of maximum and minimum response time were connected with curves to form the boundaries of a region within which the points representing execution of the command could be expected to fall. Figure IIB-5 shows the results of this plot for a command that executes a two-word search when the number of references corresponding to each word in the search

expression is 1000. It can be seen from this figure that all but one of the points fell on the boundaries of the region. That is, response time for this command was either very good (about six seconds) or it increased directly with the number of active users and to a maximum of more than two minutes. Similar results were obtained

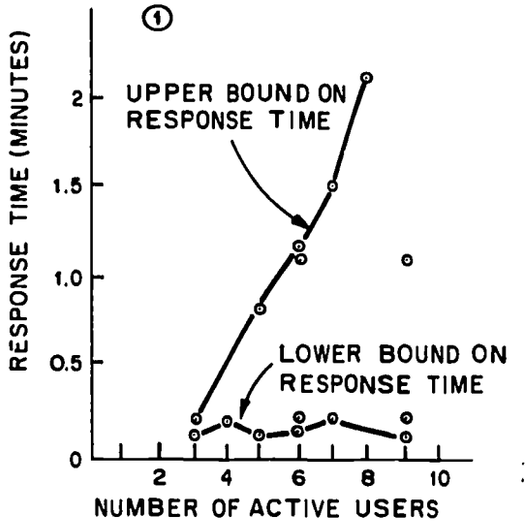

Fig. IIB-5 Relation Between Response Time and Number of Active Users for a Two-Word Search when the List for each Word Contains 1000 References

for other commands. The behavior shown by Fig. IIB-5 was attributed to the system scheduling algorithm which assigns priority to requests requiring less than four seconds of computation time and executes requests requiring more than four seconds of time only after each currently pending request has received some fixed amount of computation time.

Part II yielded less data of a quantitative nature since users were asked only to conduct a search in their own style and to rate the system performance on a five-point scale at specified intervals of time. Although the results are subject to broad interpretation, it appeared that the CTSS system, which can satisfactorily support in excess of 20 users engaged in ordinary time-sharing applications, could generally support only eight to ten active Intrex users with acceptable response times.

C. DATA-BASE GENERATION

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SUMMARY

Inputting into the augmented catalog was curtailed when that data base achieved a size of 20,000 documents, more than enough with which to conduct our experiments. Plans are now underway to develop new data bases from available bibliographic magnetic-tape services so that previous results which compared Intrex and more standard indexing can be further substantiated. Various ways to optimize the new data-base structure are being considered; these will be implemented to the extent resources for doing so are available. Currently, a tentative plan for converting INSPEC tapes to Intrex format has been worked out, including the use of both controlled-vocabulary and free-vocabulary subject-indexing elements.

THE AUGMENTED CATALOG

Intrex, as a set of information-transfer experiments, initially conceived of an augmented catalog containing records for about 10,000 documents in selected areas of materials science and engineering. The data base has actually reached 20,000. This number has proven more than sufficient for conducting the experiments and should be quite adequate for completing the experiments in progress. Therefore, we have curtailed additional inputting into the augmented catalog.

At the time that further inputting was curtailed the total number of documents indexed, keyed and corrected had reached 20,050. The number of these documents that had been formatted and inverted for the online data base was 19,365. The data base in both the input and formatted forms is currently stored on magnetic tape and is available for continuation of the Intrex experiments.

USE OF EXTERNAL DATA-BASE SOURCES

In the current phase of our Intrex work we are seeking to demonstrate how commercially available bibliographic tape services can be used to help substantiate the results already obtained on our experiments. In addition, we are seeking to

demonstrate ways to use these tapes in operational systems which would be more effective than ways in which they are typically used in current systems.

In particular, we are currently planning to use some of these external sources to make actual computer-run search comparisons — not just simulated comparisons, as we have done in our previous experiments — of the effectiveness of the augmented catalog data in relation to standard catalog and index data used either in the standard ways or in the more advanced Intrex way. For example, we are setting up a new data base from external sources which has a significant overlap in documents with the current 20,000-document augmented catalog. Indexing for the new data base will be done in two ways. First, classification and other controlled-vocabulary indexing terms present on the tapes will be used. Second, free-vocabulary terms of an Intrex-like type will be automatically generated from title and abstract words. The main experimental plan, then, is to perform retrieval-effectiveness experiments similar to the type we have been doing — and, perhaps, using the same problems for which considerable analyses have already been worked out — to determine how retrieval effectiveness varies according to the indexing method.

It is recognized that the catalog data supplied by most tape services is considerably less comprehensive than Intrex augmented-catalog data. With the help of these new experiments we expect to test the results of our previous experiments and simulations which provide a quantitative estimate of the improvement in retrieval effectiveness as catalog comprehensiveness is increased. We shall also consider how the utility of bibliographic tape-service products might be increased, both in the ways these tapes are generated and in the ways they are applied. In particular, we shall analyze the extent to which a good abstract can serve as the basis for automatic and effective document indexing.

OPTIMIZED DATA-BASE STRUCTURE

In the process of planning for a new data base we are led naturally to consider ways in which the present Intrex data-base structure can be improved. While the present structure is well-suited to our experimental program, we have recognized a number of ways in which it could be improved, especially if additional functional requirements are desired in an operational environment.

One important attribute of the catalog is universality: that it be able to handle diverse document types. The Intrex augmented catalog was originally designed with this feature in mind and it appears to have served that aim rather well. However, there are several areas in which improvement seems possible, especially where the goal is to try to meld diverse bibliographic-tape sources into a common structure. One requirement for universality is to identify functionally

similar data elements for different document types and group these in a common field. While this is generally accomplished in Intrex, one improvement, for example, would be that Intrex Field 29 — Date of Publication (for books and monographs) — be associated in a single field with that element of Field 47 — Journal Citation (for journal articles) — which gives journal issue data.

Another aid to an efficient catalog structure is to keep individual data elements in separate fields rather than to group them together as is done for Intrex Field 47. This field now contains the data elements Journal CODEN, volume, issue, date, and pagination separated only by delimiters. Where it is desirable to combine several data elements for output purposes it should be possible to define a "macro field" as, for example, the Intrex Field 75 combines the three "standard" fields: 21, 24, and 47.

It is desirable to be able to tag documents with unique identification numbers so that identical documents from different sources can be recognized and results from searching different data bases, as through a network, can easily be combined. As an aid to establishing such identification, document numbers can incorporate a source parameter and a rough date parameter.

There are numerous data-handling functions that should be considered in designing a suitable data-base structure. Some of these are listed below:

- Correcting mistakes in the file
- Adding new documents to the data base at any time
- Allowing the user himself to insert comments about documents or entirely new document records
- Making the results of catalog searches available for additional processing, such as editing, sorting, and publication — either by modules in the retrieval system itself or by suitable interfacing with separate programs
- Making the catalog search easily expandable to searches on new fields and new data types and/or interfacing the bibliographic search with more general searching
- Incorporating thesaurus aids within the inverted-file structure.

At present, because of limited resources for carrying out our experiments, we do not expect to be able to revise our programs to accommodate all the above-listed functions to any great extent. However, to the extent that we do not implement some of these features, we hope to document in future reports our ideas as to how they might be handled.

STATUS OF NEW DATA-BASE GENERATION

Several bibliographic tape services have been studied in some detail for their potential use in the new Intrex experiments. The INSPEC tapes have so far been found most promising in terms of (1) overlap with current Intrex data base, (2) catalog contents with sufficient information to enable experimentation, and (3) potential for use in future data bases for M.I.T. A tentative correspondence of INSPEC catalog fields with Intrex fields has been identified. A sample INSPEC tape was input to the CTSS disc and converted to a code suitable for selected output dumps so that source tape particulars and statistics could be determined. (See Section D for details of the software involved.)

A tentative plan for generating subject terms automatically from the INSPEC types has been completed. Title words will be used as they are currently in Intrex. The INSPEC classification term and its translation as an English phrase will become Intrex range-0 expression. INSPEC controlled-vocabulary index terms will become Intrex range-1 expressions. INSPEC free-vocabulary terms will become Intrex range-2 expressions while sentences in the abstract will become range-3 expressions. In order to keep inverted-file storage from becoming too costly it may be desirable to extend the list of exclusion words and to drop redundant instances of free-vocabulary and abstract words. We expect our new experiments to test the validity of conclusions drawn from previous experiments, namely, that such storage-saving devices will not decrease retrieval effectiveness to any significant extent.

D. COMPUTER SOFTWARE

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SUMMARY

New features were added to the Intrex retrieval programs to enhance a user's capability to interact with the system. These are, a command for changing the size of characters displayed on the ARDS terminal, an ability to redisplay previous parts of an interactive session at the ARDS, and an improved method for saving and restoring lists of retrieved documents.

Development of software for creation of an Intrex data base from INSPEC tapes has begun. A program to bring the tape information onto the CTSS disk and another program to translate the information from the INSPEC character set to an ASCII representation have been coded and debugged.

Software for the buffer/controller of the BRISC terminal is in final operational form. A report describing the buffer/controller software and its associated support programs is in the process of publication.

INTREX RETRIEVAL PROGRAMS

Two important new features were added to the Intrex retrieval programs. The first of these permits a user to control the size of characters appearing on the ARDS display screen. This capability has been met with enthusiasm by our users in the open environment since it can be used to improve legibility of material appearing on the ARDS screen. The user can request a total of sixteen different character sizes by typing the command

size h w

where h and w are numbers ranging from 1 to 4 and representing the character height and character width respectively (see Figure IID-1). If the size command is used with only a single argument, both h and w will be assumed to have the value of that argument. Thus only characters on the diagonal of the matrix of Figure IID-1 are represented with one argument.

A second new feature is a paging capability for the ARDS which allows a user to redisplay earlier portions of his interactive session. This capability

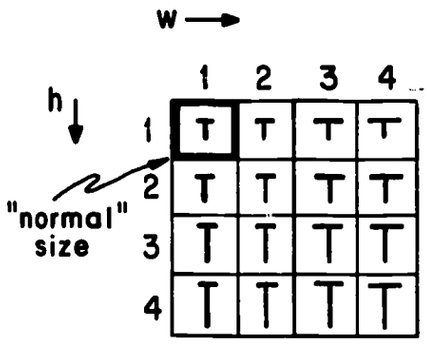

Fig. IID-1 Routing Problem for Messages Sent from Node A to Node C

which has existed on the BRISC for some time as a feature of the terminal and its buffer/controller has thus been extended to terminals that do not have the local programming and storage capability of the BRISC.

The SAVE and USE commands that allow users to save lists of document references in a personal file have been modified to overcome certain idiosyncrasies that caused some users problems. The trouble stemmed from the fact that the USE command caused a list of saved references to replace existing in-core lists. The Intrex programs now prevent inadvertant loss of these in-core lists by insisting that the user explicitly save these lists or dispose of them before bringing new lists into core.

Some of the larger and more frequently used modules of the Intrex Retrieval Programs were scrutinized with an intent to render the coding of the functions these programs carry out as efficient as possible. While no actual recoding of these programs was attempted, an explicit set of design changes was identified that should be of use in a recoding or conversion of the retrieval programs at a later time.

DEVELOPMENT OF DATA BASE FROM TAPE SERVICE

Two programs related to the development of an Intrex data base from the INSPEC tape service have now been written and debugged. The first of these permits the bringing of the information as represented on the INSPEC tape onto the CTSS disk. While INSPEC tapes are compatible with the tape drives currently used on the IBM 7094, the tapes are not directly readable under the CTSS operating system because of their physical format. Intrex programmers therefore wrote a program that runs on the IBM 7094 as a batch-processing job; the program reads the INSPEC tape and writes the information on another tape that can be read by CTSS. The informa-

tion on this new tape can then be brought onto the disk using standard CTSS utility programs.

The second program converts the disk-resident information obtained from the INSPEC tape from INSPEC's special character code to a subset of the ASCII code. The file can then be listed and otherwise processed using already available programs.

Yet to be written are programs that will read the INSPEC catalog records, index them automatically, and reformat and process the records to generate an Intrex data base.

BUFFER/CONTROLLER SOFTWARE

Software for the buffer/controller of the BRISC terminal system has been debugged and is in final operational form. A report has been prepared that describes the programs used during operation of the BRISC terminals. Also contained in the report are descriptions of programs used in support of the BRISC console programs (for assembly, editing, and debugging), as well as descriptions of the special commands used to communicate with the drum. Publication of the software report should approximately coincide with publication of this activity report.

E. ECONOMIC ANALYSIS

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SUMMARY

Research on topics related to the economic modeling of information systems has continued. A more general framework for this analysis is evolving, and several problems related to optimizing operation of information systems with a variety of characteristics are now tractable.

ECONOMIC ANALYSIS OF INFORMATION SYSTEMS

Economic analysis and modeling has continued. Dr. Therrien presented a joint paper with Professor Reintjes on this subject at the Sixth Annual Princeton Conference on Information Sciences and Systems. The full text of the paper appears in the Conference Proceedings and covers topics described in the preceding semi-annual reports.

Currently, an attempt is being made to place the techniques used in our modeling of information systems in a more general framework. This will prepare the way for the analysis and optimization of models that describe information systems of different types to almost any level of detail.

The general framework begins with an identification of the types of mathematical functions that represent costs and revenues. Cost functions usually have as arguments some measures of the amount of a service provided or the capacity of the system to provide such a service. The functions are often discontinuous in nature, that is, there exist points at which an arbitrarily small change in of the arguments (corresponding to a change in service or service capacity) produces a very definite jump in the cost.

Revenue functions relate the total amount of revenue obtained in providing a product or service to some measure of the amount of the product or service made available and the price. Revenue functions are generally continuous functions that tend to exhibit the principle of "diminishing returns". That is, the greater the amount of a service or product made available to users, the smaller is the increase in revenue for a fixed small increase in the amount of the product or service.

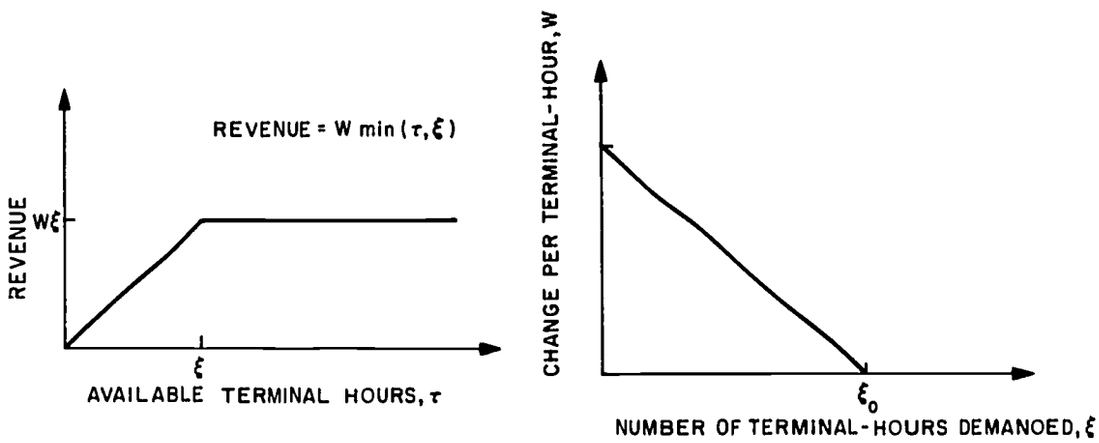
Having defined the general form of the functions to be dealt with, one can then choose appropriate mathematical techniques to answer questions of system

analysis and optimization. For example, one can seek to determine a policy for charging system users that maximizes profit, the difference between revenues and costs, subject to certain constraints. One such constraint is the market-demand curve which relates the amount of service users will purchase to the price of the service. Alternatively, one can impose constraints on the profit; for example, if it must be non-negative, one can determine the least charge to users that is consistent with the constraint.

The solutions to these problems are not obvious even in relatively simple cases. For example, consider the following simple model of an on-line information-retrieval system. Costs are assumed constant at C_o. Revenue is expressed by

$$\text{Revenue} = W \min(\tau, \xi)$$

where W is the charge per terminal-hour of service, τ is the number of terminal-hours the system is made available, and ξ is the total number of terminal-hours of service demanded by the user community (see Fig. IIE-1(a)). The market demand is approximated by the straight-line relation shown in Fig. IIE-1(b). It can be shown



(a) Simple Revenue Function (b) Stroight-Line Demand Curve

Fig. IIE-1 Functions Used in a Simple Charge-Optimization Problem for On-line Information Systems

that the charge to users that maximizes profit is

$$W = \frac{\xi_o}{2\beta}$$

where ξ_o is the number of terminal-hours of service demanded by the user community when there is no charge, and $1/\beta$ is the negative slope of the demand curve. The minimum charge to users that maintain a non-negative profit is given by

$$W = \frac{\xi_o}{2\beta} - \sqrt{\left(\frac{\xi_o}{2\beta}\right)^2 - \frac{C_o}{\beta}}$$

Note that if the fixed costs C_o are greater than $\xi_o^2/4\beta$, W becomes a complex number. This simply indicates that for those values of fixed costs it is not possible to find any charge that can render the profit non-negative.

The simple example cited here is meant to only give a flavor of the kinds of results that can be obtained from our approach to economic analysis of informations systems. The advantage to formulation of the problem in a general context is that techniques that apply to the analysis of simple models also apply to more complex and detailed models. Only the algebraic manipulations and the form of the final results are different.

F. INFORMATION NETWORKS

Staff Members
Dr. C. W. Therrien

Graduate Student
Mr. H. V. Jesse

SUMMARY

A thesis was completed by Mr. H. V. Jesse on the topic of digital communication networks for information storage and retrieval. Such networks would be the means by which users could interrogate and interact with many remote data bases from a single terminal. The thesis sought to answer questions related to required channel capacity for the communication links, expected time delays in the network, local buffer-storage requirements, and routing strategy for message requests from source to destination.

ANALYSIS OF INFORMATION NETWORKS

An information network as defined here involves the interconnection of information retrieval computers with high-speed data links so that data, organized as "messages", can be transmitted from one computer (node) to another. The network is said to be of the store-and-forward type if messages may upon transmission, pass through intermediate nodes where they are temporarily buffered in queues before being sent on to their destination. The storage capability is provided by a small processor which collects incoming messages as well as messages from the local computer, and routes these messages in accordance with an algorithm to the next node along a path to their destination.

Several topics were studied in the analysis and modeling of store-and-forward networks for information retrieval. An early topic consisted in the determination of the approximate channel-capacity requirements for interconnecting the computers. An analysis was made of the number and type of commands issued by a user during an interactive search. These commands represent calculable amounts of data that must be transmitted per unit time from the data base to the local computer over the network. For an information retrieval system with 120 simultaneous users, it was found that the average data rate was 24,000 bits per second. Since high-speed lines rated at 50,000 bits per second are available from the common carriers, it was decided to center the analysis around networks consisting of these 50-kilobit links.

A stochastic model for the network was developed with assumed Poisson arrival rates for messages at the nodes and exponentially distributed message lengths. Based on this model, an expression was derived for the total delay encountered by a message in traveling from node of origin to a node of destination through a number of intermediate nodes. The total delay consists of three additive factors, namely, the electrical transmission delay (usually negligible), the delay imposed by the finite rate at which messages can enter a channel of finite capacity, and the time spent waiting in queues at intermediate nodes. In addition, an expression was derived for the probability that buffers at the nodes would become full and could not accept further messages. This expression is most often used in reverse to determine the storage capacity needed at the nodes to achieve a probability of overflow less than or equal to some given small number ε.

The results of simulations based on the model and the traffic conditions cited earlier show that delays in a network with 50 kilobit links are on the order of 25 milliseconds. Buffers at each node capable of storing six 1000-bit messages are sufficient to insure that the probability of overflow is less than 0.0005. These results indicate that interactive searching can be conducted over such a network without any considerable degradation in response time and without the need for large amounts of local storage.

Other topics of the network research consisted of parametric analyses and trade-off studies for alternate message-routing schemes, channel capacities, buffer lengths, and so on. For example, in the network of Fig. IIF-1, incoming messages

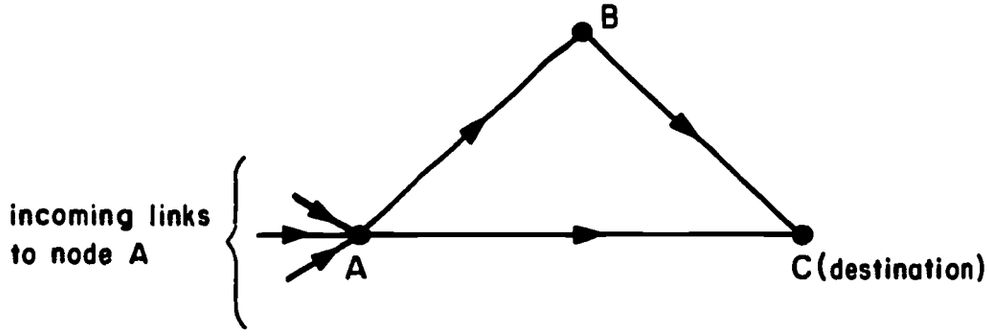


Fig. IIF-1 Character Fonts Represented by Intrex SIZE Command

arriving at node A can be sent to node C (the destination) via the direct path AC or via the indirect path ABC. A strategy that minimizes the average delay in transmitting messages from A to C depends on the channel capacities of each link, the buffer sizes, the arrival rate of messages at node A and the message lengths. For

fixed values of these parameters, the overall message delay can be plotted as a function of distribution of the messages between the two paths. Figure IIF-2 shows that for a relatively high arrival rate of 80 messages per second 63 percent of all incoming messages should be sent along the direct path AC and 38 percent should be sent along the indirect path ABC in order to achieve minimum delay. For a relatively low arrival rate of 26 messages per second, nearly all messages should be sent along the direct path AC.

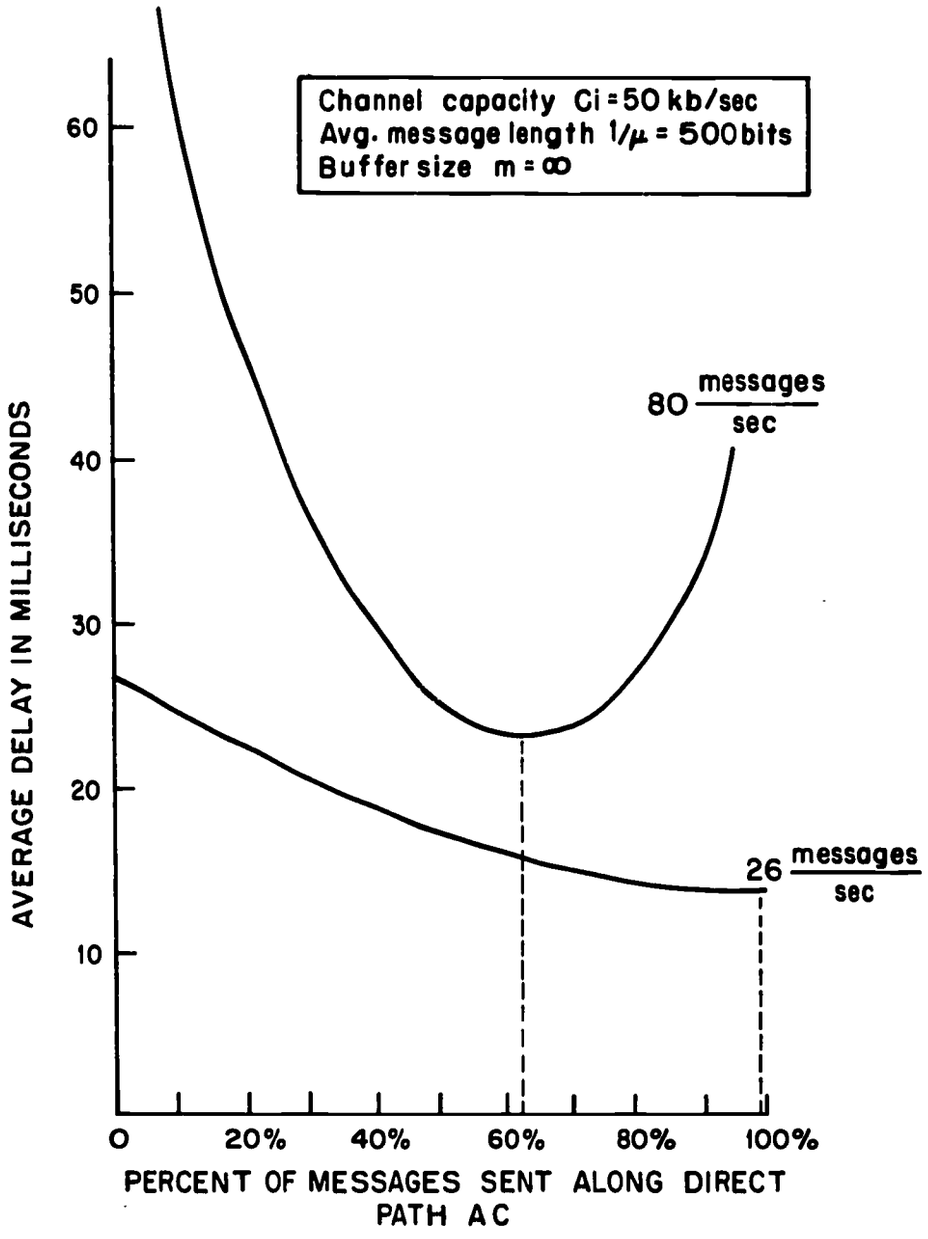


Fig. IIF-2 Delay as a Function of Message Distribution

G. HARDWARE

Staff Members

Mr. J. Bosco
Mr. P. Campoli
Mr. J. E. Kehr
Mr. D. R. Knudson
Professor J. F. Reintjes
Professor J. K. Roberge

SUMMARY

Curves describing the performance experience of the Intrex microfiche storage and retrieval devices have been prepared. Records accumulated over a 15-month period from April 1971 to June 1972 indicate an overall average of 136 successful retrieval cycles per malfunction with continuing improvement during that period.

PERFORMANCE EVALUATION OF THE INTREX STORAGE AND RETRIEVAL DEVICES

Daily operational records have been used to evaluate the performance of the microfiche retrieval devices used in conjunction with the text-access system. The study extends from April 1970 to June 1972 and includes the approximate period during which Project Intrex provided daily service to a selected group of the M.I.T. community.

The retrieval devices are modified CARD (Compact Automatic Retrieval Display) units, manufactured by Image Systems, Inc. as desktop, self-contained, microfiche-file readers. Each system has a storage capacity of 750 microfiche and is engineered to be operated from a pushbutton control panel by office personnel. Each microfiche is fastened to a uniquely notched 12-bit binary-coded metal clip and is filed inside the unit in a rotary drum. An internal light source projects the microfiche image through a folded optical path onto a translucent screen. The basic CARD consists of six major mechanical sub-assemblies: a carousel, carousel motor, selector, spreader, X-Y positioner and optical system. These sub-assemblies are of modular construction and are readily accessible for replacement and maintenance.

The CARD devices were chosen to store the microfilmed Intrex document collection because of their compact size and low cost, and because their storage capacity matched the size of the Intrex data base. To integrate the units with the text-access system major alterations in hardware had to be performed. The manufacturer's optical system and translucent viewing screen were removed and a lens system, photomultipler tube, and control circuit modifications were installed. The

lenses, photomultiplier tube, and an adjacent high-resolution cathode-ray tube comprise the elements of a flying-spot scanner.*

Electronic switches and logic were added to the control-panel circuitry to provide automatic as well as manual control of the retrieval devices. The modified CARD units are now similar to the originals only in that the mechanical retrieval assemblies, namely the carousel, carousel motor, selector, spreader, and X-Y positioner,have been retained. Presently, the text-access central storage and retrieval system employs two retrieval units shared by a single scanner to provide access to the 1500-fiche data base.**

The first retrieval device was purchased in mid-1968 from Nuclear Research Instruments, a division of Houston-Fearless Corporation. This division later separated from Houston Fearless to become Image Systems, Incorporated. The first unit was an early production model and was modified by the manufacturer according to M.I.T.'s specifications. The second retrieval device, a later and improved CARD unit, was purchased from Image Systems, modified by Intrex personnel, and added to the text-access system early in 1970.

From March 1970 to April 1971 the performance records consisted of malfunction data only and did not include the number of retrieval cycles between failures. The malfunctions were of two basic types: equipment failures, such as a broken spring or defective microswitch, and microfiche jamming during fiche selection or frame positioning. Other malfunctions, where a requested document is not retrieved but the system responds properly to subsequent requests, are usually not reported and, therefore, not included in the malfunction statistics. During these initial operations poor reliability resulted in an average of one malfunction per day. The major factors contributing to these malfunctions were:

1. The first retrieval device was an early production unit and contained many inherent defects which had not yet been corrected by the manufacturer.

2. Both devices were modified to be compatible with Intrex, and in the process some factory-adjusted mechanisms were misaligned.

3. Microfiche stored within the retrieval units were printed on an acetate-base film. This type of film curled in time and frequently caused fiche to jam during retrieval cycles.

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* Jagodnik, Anthony J. Jr. "Performance Evaluation of Image Storage and Transmission Systems", ESL-R-391, June 1969.

** Intrex Semiannual Activity Report, 15 March 1970.

An effort was undertaken to improve the reliability of the retrieval devices by replacing defective fiche and producing all additional fiche on polyester-base film. A more rugged base than acetate, polyester is less likely to curl from temperature variations, humidity, and wear. These measures improved the system performance to some extent, but the Intrex user logs show that during the fall of 1970 the retrieval devices were still far from reliable.

Finally, Image Systems personnel were consulted about the reliability problems that M.I.T. was experiencing with the modified CARDs. They recommended a major overhaul of the older retrieval unit and that a calibration of the newer unit be performed by their company technicians. They further recommended that a six-months service contract be purchased by M.I.T. for the maintenance and repair of both retrieval devices by their Boston field representative. These suggestions were accepted and the first unit was retrofitted with updated and improved mechanical assemblies. The retrofit was completed in April of 1971 and a service contract was written for the period May 1 through October 31, 1971.

A complete record of the retrieval-system performance has been documented since April 1971 and is summarized in Figs. IIG-1, G-2, G-3, G-4. Figure IIG-1a

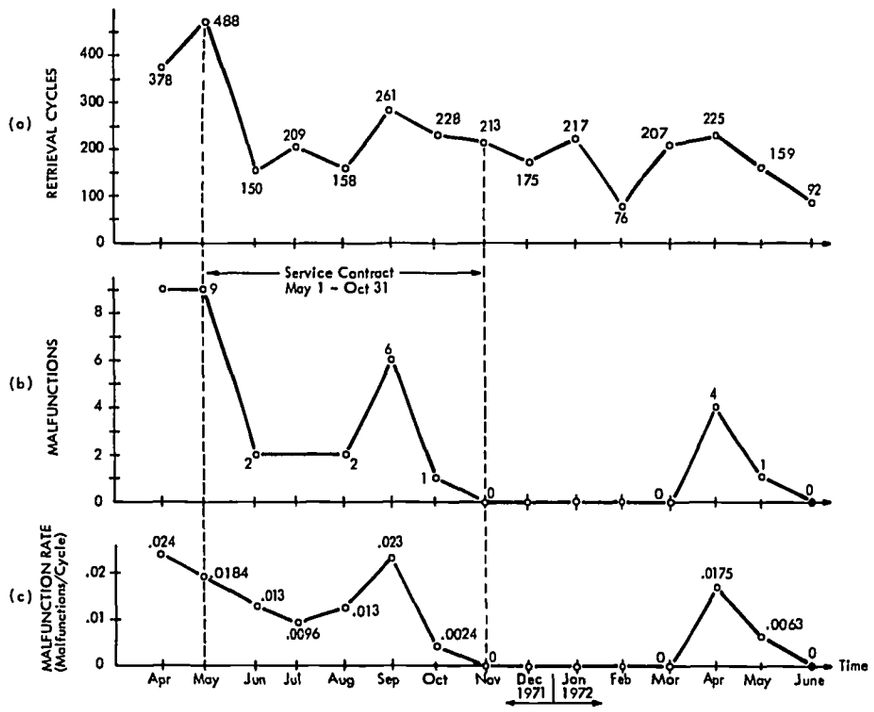

Fig. IIG-1 Performance Record of Retrieval Unit #1

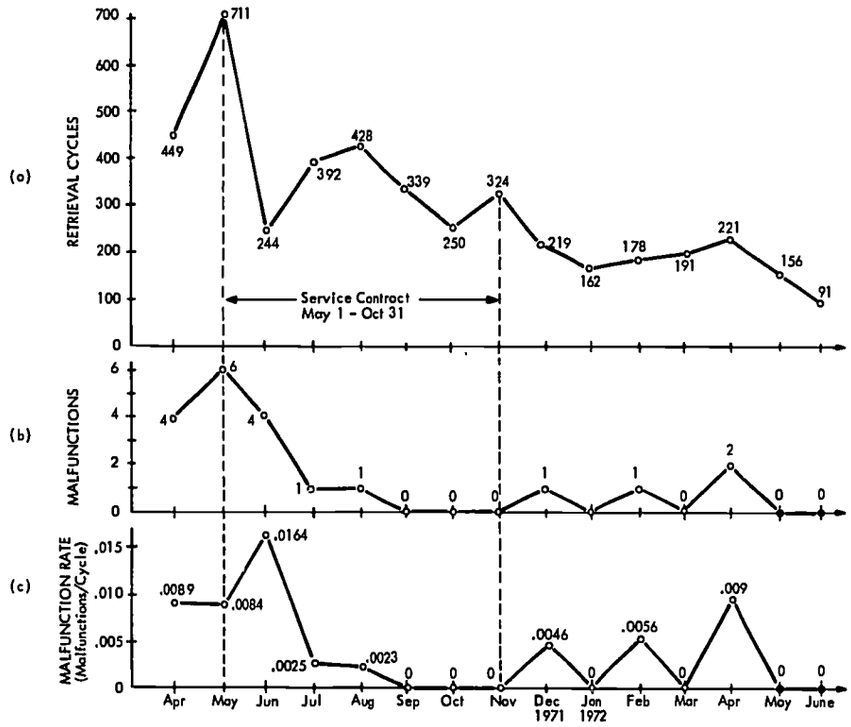

Fig. IIG-2 Performance Record of Retrieval Unit #2

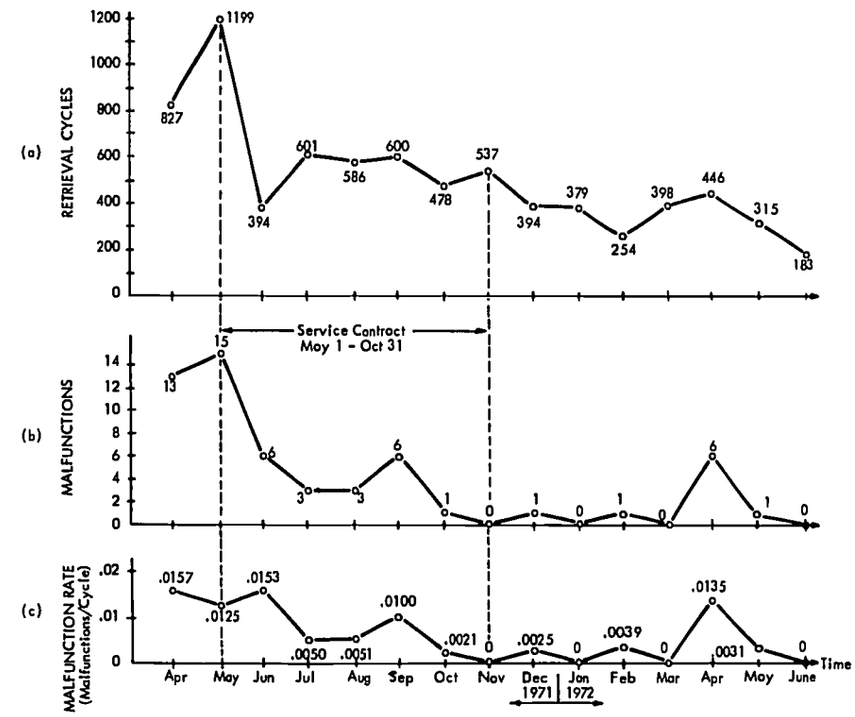

Fig. IIG-3 Combined Retrieval Performance Record

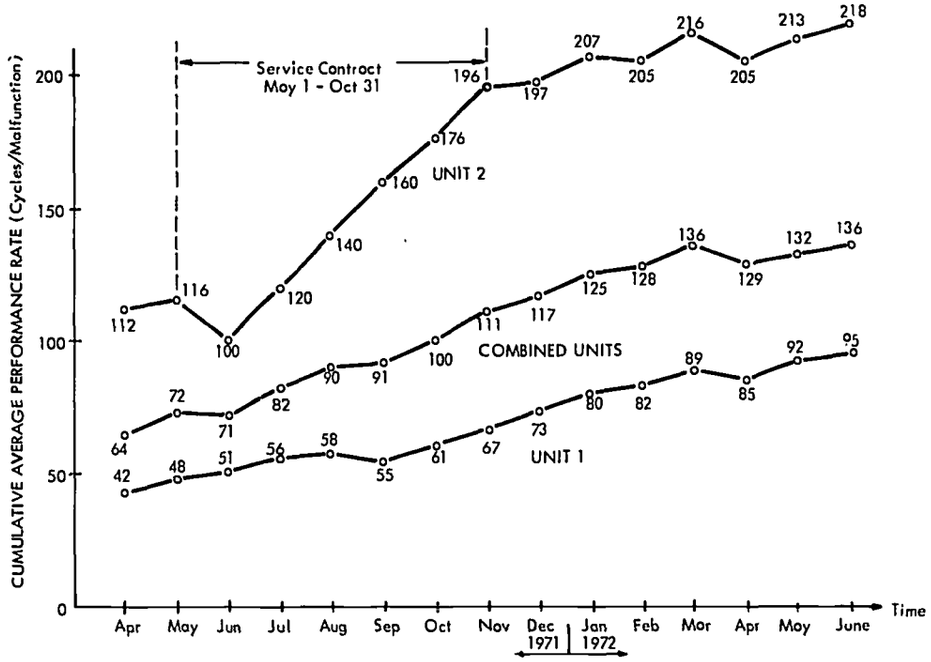

Fig. IIG-4 Cumulative Performance Record

illustrates the number of retrieval cycles made during each month on Unit 1 for the period from April 1971 through June 1972. A retrieval cycle is defined as a text request which requires the selection of a new fiche by the retrieval device from the carousel. Retrieval cycles are recorded on counters located in the retrieval devices. Because all text requests do not require the selection of a new fiche, the number of retrieval cycles represent only a portion of the total number of text requests. It is estimated that about one text request out of six requires the selection of a new fiche.

Shown in Fig. IIG-1b is the number of malfunctions which occurred each month. The nature of these malfunctions is described earlier in this section. A better measure of performance is the malfunction rate, plotted in Fig. IIG-1c, which is calculated by dividing the number of malfunctions by the number of retrieval cycles for each month.

Figures IIG-2 and IIG-3 illustrate the performance of unit 2 and the combined performance of both devices in a manner identical to that of Fig. IIG-1. Parts (a) and (b) of Fig. IIG-3 were obtained by adding the corresponding parts of Figs. IIG-1 and 2 to produce the total retrieval cycles and malfunctions per month. Figure IIG-3c was calculated by dividing the total number of malfunctions from Fig. IIG-3b by the total number of retrieval cycles from Fig. IIG-3a.

Figure IIG-4 is drawn to illustrate trends in the cumulative average performance rate of the separate and combined retrieval devices. The cumulative average performance rate is found by dividing the total number of retrieval cycles for a particular unit which have been made from April 1971 to the month in question by the total number of malfunctions which have occurred over the same period of time. More specifically, the cumulative average-performance rate is determined by the following equation:

$$\overline{PR}_j = \frac{\sum_{i=APR'71}^{n} (RC_j)_i}{\sum_{i=APR'71}^{n} (M_j)_i}$$

where $\overline{PR}_j$ = cumulative average performance of unit j

$(RC_j)_i$ = total retrieval cycles of unit j during month i

(M_j) = total number of malfunctions of unit j during month i

i = a month in the time period under consideration

j = the device in question; either unit 1 or 2, or the combined units

n = the last month in the period for which the cumulative average performance rate is being calculated.

DISCUSSION OF RESULTS

Observations of Figs. IIG-1 through 4 show that a continuing improvement in performance has been obtained from the beginning through the end of this study. As illustrated by Fig. IIG-4, the most significant improvement occured during the Image Systems service contract period from May 1 through October 31, 1971. During this period the retrieval devices were carefully adjusted and calibrated according to factory procedures until all mechanical problems were eliminated.

The remaining malfunctions were due mainly to microfiche defects. As new polyester-base fiche were added to the system to replace the older acetate-base fiche, the quality of the microfiche store was improved. This accounts for the noticeable continuing, but somewhat slower, increase in the performance rates. The microfiche store was also checked periodically throughout the entire time period for defective microfiche clips and several of these were replaced.

From Fig. IIG-4, the average performance for the combined retrieval units over the entire 15-month period is 136 retrieval cycles per malfunction which is at least an order of magnitude lower than the manufacturer claims for other installations.

The discrepancy can be attributed to several factors:

(1) Our experience emphasizes the importance of adjustment and maintenance towards reliable performance of the retrieval devices. Because of the Intrex modifications and the lack of trained maintenance personnel and special calibration equipment, the same performance cannot be expected from the Intrex units as other installations of factory-calibrated units serviced by full-time maintenance personnel. The marked improvement after manufacturer alignment and adjustment and during the maintenance contract illustrates the performance effect of this factor.

(2) The Intrex environment represents a more severe test than most installations. The unattended, automatic operation of the Intrex units prohibits operator interaction which might avoid or alleviate some device malfunctions. Also, the experimental nature of Intrex leads to more tinkering with these devices than would be encountered in an operational system.

(3) Many of the malfunctions, particularly early in the period, are not directly attributable to the retrieval devices. A non-curl film base, such as polyester, is essential to good performance. Also, re-using the encoded metal clips leads to their bending or being insecurely attached to the fiche, both of which are likely to result in a retrieval malfunction. The continuing rise in performance illustrated by Fig. IIG-4 is primarily the result of purging defective fiche and clips from the system. During the last 8-month period after the service contract termination, the average performance rate has been 323 retrieval cycles per malfunction.

III. MODEL LIBRARY PROJECT

A. STATUS OF THE PROJECT

Mr. J. J. Gardner

This reporting period has seen the continuation of work on the existing programs within the Model Library Project. Major emphasis has been placed on increasing the utility and availability of the results of the staff's work to the library community.

The wide acceptance of Library Pathfinders has lead to successful negotiation with the Addison-Wesley Publishing Company to ensure the uninterrupted availability of Pathfinders beyond the existence of the Model Library Project in its present form. Beginning this fall Pathfinders will be distributed by Addison-Wesley; editorial responsibility will remain with the Model Library Project. This arrangement will ensure the continuation of the program while it increases the distribution of Pathfinders.

Two new point-of-use programs have been completed; one existing program has been revised; two new programs are underway. The sharing of all programs has increased and response continues to be enthusiastic.

In a related project, a general library orientation program is being prepared. The objective is to produce a program of particular relevance to the users of the Barker Engineering Library while simultaneously serving as a basis for orientation programs at other engineering research libraries.

The user preference study continues to indicate user acceptance of microfiche copy when high quality reading and copying equipment are readily available. Microfiche and hard copy were each offered to users at no cost for a four-week period; the results of this study are interesting and to many, perhaps surprising.

The non-print media area has been installed within the Barker Engineering Library and equipment has been purchased. Locating, selecting, and organizing software for this area is a continuing concern, but this academic term should see significant use of the area.

During this reporting period some forty librarians from academic and public libraries attended day-long seminars on Project Intrex and the Model Library Project. Their professional response has been invaluable in assisting the Model Library staff in renewing and directing their efforts.

B. POINT-OF-USE INSTRUCTION

Staff Members

Mr. J. J. Gardner
Ms. K. M. Boos
Ms. M. P. Canfield
Ms. S. B. Hendrich

Six point-of-use instruction aids in the Barker Engineering Library continue to introduce users to: the subject catalog; the author-title catalog; the Intrex System; Engineering Index; Science Citation Index; and NASA STAR. The three program formats tested through these aids are synchronized sound-filmstrip (subject catalog, author-title catalog), synchronized sound-slide (Intrex, Engineering Index) and audio cassette with sample pages (Science Citation Index, NASA STAR).

Several new programs have been recently completed: Chemical Abstracts; a combined program on International Aerospace Abstracts and NASA STAR; and a revision of Science Citation Index to accommodate format changes in that index. The programs on Chemical Abstracts and IAA/STAR are each ten minutes long and utilize audio cassettes with sample pages. Audio with sample pages continues to be the preferred format for several reasons: the equipment is less expensive to develop and more easily maintained than either the sound-filmstrip or sound-slide units; the programs can be produced and duplicated more quickly and less expensively; and users indicate they gain more from the instruction aids by seeing the actual pages rather than photographic displays of the pages.

Feedback on the various programs is obtained from questionnaires placed with each aid in the library. Sufficient data have been received from the Science Citation Index, Engineering Index, NASA STAR, and subject catalog programs to measure user response to the point-of-use instruction programs as learning aids.

Total Number of Respondents	Responses	Percent (N=85)
Undergraduates	29	34
Graduate Students	15	18
Staff/Faculty	13	15
Other (non M.I.T.)	26	30
No Answer	2	3

Reasons for Using Programs	Responses*	Percent (N=85)
Wanted to use source described	25	30
Started to use source; did not understand something	7	8
Curious about audiovisual aid	58	68
Other	4	5

*Several users gave more than one answer; generally they wanted to use the source, and were at the same time curious about the audiovisual aid.

Preference for a Different Means of Assistance	Responses	Percent (N=59)
Prefer another means (other than audiovisual aids)	19	32
Do not prefer another means	40	68

Other Means of Assistance Preferred	Responses*	Percent (N=19)
Individual assistance	14	74
Written instruction	9	47
Library orientation tour	5	26

*Nine users checked two answers.

Data on individual programs are as follows:

Subject Catalog	Responses	Percent (N=11)
The aid was extremely helpful	0	0
very helpful	1	9
moderately helpful	4	36
slightly helpful	5	46
not helpful	1	9

Subject Catalog	Responses	Percent (N=11)
The aid was helpful because:*		
It made me aware of the source	1	9
I learned new things about the source	3	27
It refreshed my memory about the source	5	45
It was too elementary to be helpful	3	27
Other	0	0

*One user checked two answers.

NASA STAR	Responses	Percent (N=12)
The aid was extremely helpful	3	25
very helpful	4	33
moderately helpful	5	46
slightly helpful	0	0
not helpful	0	0
The aid was helpful because:*		
It made me aware of the source	5	42
I learned new things about the source	5	42
It refreshed my memory about the source	2	17
It was too elementary to be helpful	2	17
Other	0	0

*Two users checked two answers.

Science Citation Index	Responses	Percent (N=27)
The aid was extremely helpful	3	11
very helpful	14	52
moderately helpful	8	29
slightly helpful	1	4
not helpful	1	4

Science Citation Index	Responses	Percent (N=27)
The aid was helpful because:*		
It made me aware of the source	15	56
I learned new things about the source	13	48
It refreshed my memory about the source	4	15
It was too elementary to be helpful	2	7
Other	1	4

*Eight users checked two answers.

Engineering Index	Responses	Percent (N=34)
The aid was extremely helpful	0	0
very helpful	7	21
moderately helpful	19	56
slightly helpful	3	9
not helpful	3	9
no answer	2	5
The aid was helpful because:*		
It made me aware of the source	7	21
I learned new things about the source	17	50
It refreshed my memory about the source	7	21
It was too elementary to be helpful	8	24
Other	4	12

*Nine users checked two answers.

NASA STAR and Science Citation Index programs have been placed in the M.I.T. Science Library on an experimental basis. They are available upon request at the reference desk and advertised by signs next to NASA STAR and Science Citation Index on the shelf. One inexpensive ($30) portable audio cassette player serves for both programs; the user must load and rewind the cassette player each time a program is played. These extra steps are accepted and no problems with

using the cassette player have been reported. One advantage of the arrangement is that the user can stop the program and replay any parts of the program he did not understand the first time through.

Use of the instruction aids in the Science Library is approximately one-third that in the Barker Engineering Library, presumably because the devices must be requested at the desk.

Many institutions continue to take advantage of the loan/duplication program. Slides, tapes, sample pages, scripts, and equipment plans are sent to requesting librarians who duplicate and return the material. Since March 1972 over 125 copies of various programs have been sent to institutions in the United States, Great Britain, and Canada.

Two new programs are in preparation: Government Reports Index and Electrical and Electronics Abstracts, Series B of Science Abstracts. The Government Reports Index program is audio with sample pages and will be combined in the Barker Engineering Library with instructions on using that library's technical reports catalog. A new sound-slide unit has been designed for the Science Abstracts program. Changes include a custom made metal cabinet in which the viewing screen has been raised to eye level. In addition, the sound system will be synchronized endless loop cassette, making in-house production of sound-slide programs easier and less expensive.

Continuing efforts will include expansion of the loan/duplication program and data gathering through the questionnaires.

C. PATHFINDERS

Staff Members

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Ms. K. M. Boos
Ms. M. P. Canfield
Ms. S. B. Hendrich
Ms. T. H. Keister
Ms. R. J. Mead

Pathfinders will be published and distributed by the Addison-Wesley Publishing Company beginning this fall. The agreement between Addison-Wesley and the Model Library Project was negotiated to ensure the continuation and expansion of the program while increasing the availability of Pathfinders via a professional distribution agent. Editorial responsibility will remain with the Model Library Project and, while some details of the cooperative program will change, its essential nature will be the same.

It is expected that the majority of original compilations will continue to come from cooperating library schools. Editing will be accomplished by subject specialist librarians, with final editorial review and preparation for publication the responsibility of the Model Library staff. Libraries compiling Pathfinders in the cooperative program will receive fifteen Pathfinders for each of their prepared Pathfinders accepted for publication.

Pathfinders will be sold for $1.00 per title with full internal reproduction rights. They will be published on card stock with space for addition of local call numbers and each Pathfinder will include two catalog cards for entry into subject card catalogs. The program is directed primarily towards the library user and initial orders will include materials designed for library public relations programs.

The initial offering will be 113 engineering and science Pathfinders which have been revised and updated by the Model Library staff during this reporting period. Current plans call for forty Pathfinders to be published every three to four months. In order to offer reasonable coverage within specific disciplines, each group of forty will be divided between only two disciplines. Following publication of the engineering/science Pathfinders, coverage is expected to shift to the social sciences and humanities, including education, psychology, political science, history, and literature.

Future efforts will be directed towards organizing this publication procedure and increasing the participation of libraries in this program of shared reference activities.

D. USER PREFERENCE STUDY

Staff Members

Mr. J. J. Gardner
Ms. M. P. Canfield

The use of the Barker Engineering Library's Microform Service Area increased substantially during this reporting period. The microform collection continued to grow, particularly in the areas of report literature and professional society papers.

Most users continue to be satisfied with the available microfiche reading equipment according to questionnaire responses shown in Fig. III-1. Two new microfiche readers have recently been added to the Microform Service Area and are being evaluated.

	Number	Percent
Satisfied with Equipment	343	91
Not Satisfied	33	9
Total	376	100

Fig. III-1 Users' Evaluation of Microfiche Reading Equipment
1/1/72 - 6/23/72

Two cost ratios were studied during this period. Figure III-2 indicates user preference when duplicate microfiche was offered free and hard copy from microfiche was offered at five cents per page. Under these conditions 93 percent selected microfiche. This represents a change of only 2 percent from the 95 percent which selected microfiche during the preceding six-month period when hard copy was ten cents per page.

Type of Order	Number	Percent
Microfiche	619	93
Hard Copy	47	7
Total	666	100

Fig. III-2 Orders for Microfiche vs. Orders for Hard Copy
1/1/72 - 5/22/72

A more significant change appeared when both hard copy and microfiche were offered at no cost to the user. The results for this four-week period are shown in Fig. III-3.

Type of Order	Number	Percent
Microfiche	119	80
Hard Copy	29	20
Total	148	100

Fig. III-3 Orders for Microfiche vs. Orders for Hard Copy
5/25/72 - 6/23/72

Although the percent of users choosing microfiche decreased 13 points, a large majority (80%) continued to select fiche despite the availability of free hard copy. It should be pointed out that an artificial time lag was put on delivery of microfiche copy to make it equivalent to the wait for hard copy. Both forms were delivered 24 hours after a request was received.

Figure III-4 is a summary of the statistics for the entire 18-month program. Clearly, information in microfiche form is acceptable to most users of the Barker Engineering Library.

Type of Order	Number	Percent
Microfiche	1862	94
Hard Copy	176	6
Total	2038	100

Fig. III-4 Orders for Microfiche vs. Orders for Hard Copy
Cumulative Chart 1/1/70 - 6/23/72

The statistics on why users selected fiche during this period reinforce the earlier indications that the convenient size of fiche plays the largest role in that selection. Although the cost differential ranked second as a reason for choosing fiche, it was some thirty points lower as shown in Fig. III-5.

Reason for Choosing Fiche	Number	Percent
1. Convenient	164	58
2. Immediately Available	22	8
3. Less expensive	79	28
4. Curious about fiche	6	2
5. Miscellaneous	13	4
Total	284	100

Fig. III-5 Users' Reasons for Choosing Fiche over Hard Copy
1/1/72 - 5/22/72

During the period when hard copy was offered free, 84 percent who selected fiche did so because of its convenient size.

Those who chose hard copy had reasons as indicated in Fig. III-6. Half of the "miscellaneous" entry indicated a need to make notes on the document.

Reasons for Choosing Hard Copy	Number	Percent
1. No reader available outside library	7	26
2. Dislike fiche	1	4
3. Need for frequent referral	7	26
4. Miscellaneous	12	44
Total	27	100

Fig. III-6 Users' Reasons for Choosing Hard Copy over Fiche
1/1/72 - 5/22/72

Figure III-7 measures the effect of a user reimbursement factor in user preference. The figures indicate an increase in choice of hard copy when a user is reimbursed by his department for the expense. However, preference for fiche remains high at 87 percent.

	Number Choosing Fiche	Number Choosing Hard Copy	Total
User would be reimbursed for expense	112 (87%)	17 (13%)	129
User would not be reimbursed for expense	288 (94%)	19 (6%)	307

Fig. III-7 Correlation Between Reimbursement of Users and Choice of Hard Copy vs. Fiche 1/1/72 - 5/22/72

The user preference study has clearly indicated the following: fiche is an acceptable form in which information can be supplied to engineering library users; indeed this acceptance can develop to such a point that fiche is actually preferred over hard copy by a majority of users even when required information is offered in both forms at no cost. The essential elements at the Barker Engineering Library which make this preference possible are: the availability of rapid duplication service; microfiche readers in sufficient number; portable microfiche readers for loan; and close attention to the quality of the microfiche in the collection.

E. NON-PRINT MEDIA AREA

Staff Members

Mr. J. J. Gardner
Ms. S. B. Hendrich

Because an increasing amount of substantive research material is becoming available in film, film loop, audio and video tape, it behooves the major research library to become involved and knowledgeable in non-print media, and to foster its use by making facilities and materials readily accessible to its users. For this reason, a non-print media area is currently being developed for evaluation within the Barker Engineering Library.

The area is a self-service facility available for use during the hours that the Barker Engineering Library is open, with minimum supervision by the library staff. The area, which is 8 x 24 ft., was originally designed for media, and is equipped with built-in soundproof carrels and media shelving.

Hardware for the non-print media area has been selected on the basis of reliability, simplicity of operation, and the amount of media available in a given format. The library staff will be instructed in day-to-day operation and maintenance of the equipment and will be "on call" in case of user difficulty, but it is hoped that major problems will be avoided by using hardware proven in the past to be suitable for individual student use. Selected hardware includes a Technicolor Super 8 mm cartridge film loop projector with rear vision screen, an Audiotronics audio cassette playback deck with headphones to accommodate from one to six listeners, and a Sony model 3600 half-inch videotape player/recorder with an 11" TV monitor. A 16 mm self-threading film projector will be added in the near future.

While there is, generally speaking, a paucity of university and graduate level engineering media available, the amount is increasing, particularly through professional societies and institutions. The Barker Engineering Library now maintains a collection of approximately 30 16mm films, and 120 8mm film loops. In addition, a number of lectures and scientific demonstrations are available at M.I.T. on locally produced videotapes. All materials receive full cataloguing.

Audio cassettes may prove to be one of the most useful formats of the non-print media area. They are convenient to handle, simple to use, and relatively inexpensive to purchase and maintain. The Institute of Electrical and Electronics Engineers, the American Chemical Society and The American Association for the Advancement of Science are among the professional sources which offer symposia, conference proceedings, state-of-the-art reviews and topical information on cassette,

and such services are on the increase. As an adjunct to the non-print media area, inexpensive, portable audio cassette players will be offered for loan at the Barker Engineering Library Circulation Desk.

User response will be measured through questionnaires and interaction with the library staff. It is anticipated that a real need exists for such a facility and that it will receive heavy use beginning with the 1972 fall semester.

F. AUDIO-VISUAL ORIENTATION PROGRAM

Staff Members

Mr. J. J. Gardner
Ms. M. P. Canfield
Mr. J. M. Kyed

Preparation of a sound-slide library orientation program is underway. Scripting has been based on records of frequently asked questions within the Barker Engineering Library but has emphasized library sources and services. The program is intended to be basic and introductory; it is hoped that users will become aware of the research potential of engineering libraries and rely on the point-of-use programs and librarians for more specific information.

The program will be available to users via a sound-slide unit designed for on-demand, continuous loop play. It will be located at the entrance to the library during all hours which the library is open. User evaluation will be gathered and measured via formal questionnaires.

A major concern is that the program be specifically relevant to the Barker Engineering Library and adaptable to other engineering research libraries. Thus information specific to the Barker Library is scripted in such a way as to be easily edited for local differences; the emphasis is on reference sources available to all engineering libraries.

G. VISITOR'S PROGRAM

Staff Members

Mr. J. J. Gardner
Ms. K. M. Boos
Ms. M. P. Canfield
Ms. S. B. Hendrich
Mr. J. M. Kyed
Ms. R. J. Mead

The day-long visitor's programs continued with forty librarians attending four programs during the spring. As in the past, the value of these programs has been enhanced by the exchange of ideas among professional librarians.

In addition, presentations were made during the June Special Libraries Association Annual Meeting which was held in Boston. These included programs for the Metals/Materials Division, the Federal Reserve Bank Librarians, and the Engineering Division.

The importance of communication among colleagues has been highlighted through each of these programs. In no instance was a presentation a monologue. Rather, each was a forum emphasizing the common bond of shared problems and the advantages of shared solutions.

IV. PROJECT INTREX STAFF

A. PROJECT OFFICE

Professor Carl F. J. Overhage, Director

Mr. Jeffrey J. Gardner

B. ELECTRONIC SYSTEMS LABORATORY

Professor J. Francis Reintjes
Mr. Alan R. Benenfeld
Mr. Larry E. Bergmann
Mr. Joseph Bosco
Mr. D. J. Bottaro
Ms. Susan Foster Brown
Mr. Peter H. Campoli
Miss Margaret A. Flaherty
Mr. Charles E. Hurlburt
Ms. Margaret A. Jackson
Mr. Harold V. Jesse
Mr. James E. Kehr
Mr. Donald R. Knudson
Mr. Peter Kugel
Mr. Richard S. Marcus
Ms. Virginia A. Miethe
Mr. Michael K. Molnar
Professor James K. Roberge
Mr. James R. Sandison
Dr. Charles W. Therrien
Mr. George S. Tomlin

C. BARKER ENGINEERING LIBRARY

Mr. James M. Kyed, Acting Head
Ms. Marjorie Chryssostomidis
Ms. Barbara C. Darling
Ms. Kate Herzog
Ms. Carol L. Keator
Ms. Susan Nutter
Ms. Mary Pensyl
Ms. Carol Schildhauer
Mr. David C. Van Hoy

D. MODEL LIBRARY PROGRAM

Mr. Jeffrey J. Gardner
Ms. Kathryn M. Boos
Ms. Marie P. Canfield
Ms. Susan B. Hendrich
Ms. Terry H. Keister
Ms. Renae Mead

V. CURRENT PUBLICATIONS

A. REPORTS

Jesse, Harold V., "Interactive Information Retrieval in Computer Networks", ESL-TM-485, June, 1972. (Also E.E. Thesis, May, 1972)

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C. THESES

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E. MISCELLANEOUS PRESENTATIONS

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B. BOOK CHAPTERS, JOURNAL ARTICLES, AND CONFERENCE PAPERS

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Reintjes, J. F., "Recent Experiments with the Project Intrex Information Storage and Retrieval System." Gordon Conferences, New London, New Hampshire, 16 July, 1970.

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