

Usage Patterns of an Online Search System

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This article examines the usage patterns of the ELHILL retrieval program of the National Library of Medicine's MEDLARS system. Based on a sample of 6759 searches, the study analyzes the frequency of various commands and command options, classifies messages issued by the system, and investigates searcher error rates. The article concludes with suggestions for improving and redesigning both the program and query language.

Introduction

On-line bibliographic search systems have complex query languages and search protocols. This article examines one such system, the National Library of Medicine's (NLM) MEDLARS system, to determine what features of the system are used.* The purpose of the research is to provide quantitative evidence that can be used by system designers, system users, and educators to understand what takes place when a search is performed.

This article is a preliminary description of a sample of online searches. It contains an analysis of the usage of the various commands in the ELHILL retrieval programs of the MEDLARS system. Two of the most frequently used commands, the search statement and the PRINT command are analyzed to see how they are used and what options are used with them. The article then analyzes the categories of messages issued by the ELHILL program. This facilitates an understanding of tasks the system performs and errors users make. Finally, based on the empirical evidence gathered, the article makes recommendations for query language redesign, system redesign, and improved logging facilities.

Using the same sample, subsequent articles will address computer system performance and search strategies.

Methodology

The analysis of search system usage is based on log records of actual searches performed on the MEDLARS sys-

*See refs. [1]-[7] for a description and analysis of the MEDLARS system.

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tem. When a search is performed, each line of text that the user enters is date and time stamped and recorded in a file at the computer facility. The search system response is also date and time stamped and logged, thus making a record of the user-system interaction available for analysis.

The analysis of search behavior required a step between reading the log tapes and performing statistical analysis. That step involved writing a computer program that read the log tapes and converted each user and system transaction into fixed format records which were then analyzed. This process was complex because of the nature of the query language and the way in which the data are logged. For a description of the process used to perform the transformation, see ref. [8]. Once the log records were processed by the parser, a statistical analysis was performed using the Statistical Analysis System (SAS) computer programs.

Previous Research

A number of studies have been conducted to quantify the usage of online search systems. Fenichel [9] provides a good summary of them. One of the most comprehensive studies, performed by Borman and Dominick [10], described a monitoring facility, characteristics of user searches, and results of questionnaires administered to users.

Penniman has also performed a number of studies [11-14]. While primarily emphasizing modeling, his articles contain descriptive information on search characteristics as well.

One report by Penniman describing a study of the ELHILL system is particularly relevant to the present study. In ref. [15] Penniman divides searchers into three groups based on the number of hours they searched during a sample period, then analyzes the patterns of each group's searching activity. Little of Penniman's investigation overlaps with the present study, but some of his hypotheses are confirmed here. For example, his finding that users have difficulty with the logon procedure was confirmed in this research. Penniman also examined errors made by searchers, but his approach was different from the present one, and consequently the results are different.

Cain [16] performed a preliminary analysis of the ELHILL system focusing on the frequency of use of commands by the type of institution performing the searching.

Description of the Searches

The sample of searches used in this study was selected from more than 60,000 searches performed during 1979 on the MEDLARS system. The sample consists of 6759 searches conducted during eight days in late August and early September 1979. The searches are somewhat unevenly distributed by day of week, with 11% occurring on Monday, 15% on Tuesday, 25% on Wednesday, 26% on Thursday, and 23% on Friday.

They are evenly distributed by the time of day they began: 8% began before 9 AM and during each hour block interval up to 6 PM, roughly 8–11% of the searches occurred. Only 5% of the searches began after 6 PM.

The log record of these searches amounted to over 630,000 raw data records. Once processed by the parser [8], they were synthesized to about 264,000 records. In analyzing the input file, the program was able to successfully parse 99.7% of the records.

Search sessions vary considerably in length. Thirteen percent of all the sessions in the sample lasted less than one minute, perhaps indicating difficulty with telecommunication connections to NLM or difficulty with the logon procedure. It is unlikely that these represent completed searches. Twenty-eight percent of the searches lasted from 1 to 5 minutes, 18% from 6 to 10 minutes, 12% from 11 to 15 minutes, 8% from 16 to 20 minutes, 5% from 21 to 25 minutes, and 16% longer than 25 minutes. The median search session length was 8 minutes.

Another indication of the fluctuation in session size is the number of pairs of user-system interactions. (A pair consists of one user input and a program response.) An average session was composed of 40 interactions, but the maximum found in the sample was 464.

There is also wide variation in the number of characters of text a user enters on a single line. The average is close to 15 characters, but nearly 22% have three characters.* Twenty-five percent of the lines are 4 to 10 characters long, 29% are 11 to 20 characters, 14% are 21 to 30, and 10% are longer than 30 characters.†

Table 1 shows that nearly half of the 10,265 files used in the sample of searches were on the MEDLINE file. CATLINE and TOXLINE were the next most heavily used. An average search used 1.5 different files.

*Many of the three character lines are the word "yes" further discussed in the next section.

†The program that writes the user and program text onto a log file only records the first 57 characters of the text. Ideally one might want the entire text. Since only 3% of the user lines were longer than 50 characters, a length of 57 seems a good choice for input. Program responses, especially the results from printing citations are often quite long. Clearly, deciding what number of characters of program response to log is difficult.

TABLE 1. Frequency distribution of files searched ($n = 10,265$ file users).

File Name	Percent of Searches Using this file
MEDLINE	47
CATLINE	11
TOXLINE	11
CHEMLINE	7
CANCERLINE	5
HEALTH	4
SERLINE	3
RTECS	2
SDILINE	2
AVLINE	2
TOXICOLOGY	2
All others	4
Total	100

User Commands

User commands are instructions issued by the user to the search program to initiate or continue processing a search. Commands of the ELHILL system are listed in Table 2 along with the frequency and use in the sample. (A description of the use of the commands can be found in ref. [17].)

The most frequently used command in the sample was the search statement which occurred 43% of the time. The next section of this article analyzes the form of the search statement.

The second most frequent command (though in actuality a response) was the word "yes." Nearly 48,000 instances of this were found in the sample. In a number of situations this is an appropriate response. The most likely occurs when a search statement uses up the amount of time initially allocated to perform its operation, or lines printed by a PRINT command reach a specified limit. In this case the ELHILL program notifies the user of a "time overflow" and asks whether to continue printing. The user can answer "yes" or "no."

The third most frequent command is the PRINT statement. Seventeen percent of all commands were PRINT requests. Usage of this command is analyzed in a subsequent section.

The Search Statement

The search statement is the most complex in the ELHILL language. The statement is used to specify the terms to be searched in the database. The terms can be linked together with the binary operators AND and OR, and they can include the unary operators NOT, ALL, and EXPLODE.* Ranging operators such as LESS-THAN, GREATER-THAN, and FROM-TO can also be used. Previous search statement results can be combined and subheadings and category qualifiers included to refine the search.†

*ELHILL requires the AND operator precede the NOT operator. When NOT is used in this article it should be interpreted as AND NOT.

†See [17] for a discussion of the use of these options in searching.

TABLE 2. Usage frequency of ELHILL commands.

Command	Description	Frequency of Occurrence	Percent Distribution
/LOGIN	Begins login process	6759	3
CAPS	Forces output to terminal in upper case	0	
COMMENT	Allows user to send messages to MEDLARS Management staff	0	
DIAGRAM	Displays logical structure of search	0	
Disconnect**		3671	2
ELEMENTS APPLY	Changes type of terms searched for in index	0	
ELEMENTS INCLUDE		0	
ERASEALL	Clears all previous search statements	0	
ERASEBACK	Selectively deletes search statements	0	
EXPLAIN	Elaborates on last program message	59	*
FILE	Changes from one file to another	6304	3
FILES	Gives names of all data bases in system	0	
FINISHED	Signals end of OFFSEARCH, STORESEARCH, or COMMENT	0	
HELP		7	*
MESHNO	Retrieves a MeSH number for a term	14	0
Multi-meaning response***		5019	2
NEIGHBOR	Finds terms alphabetically adjacent to term supplied	432	*
NEIGHBORDETAILED	Lists each form of a main entry term	0	
NEWS	Gives news from NLM	380	*
NO	Response to many program messages	407	*
OFFSEARCH	Initiates a request for off-line search of a data base	1806	*
PRINT	Displays search results	36069	17
PURGESEARCH	Removes a STORESEARCH from the system	0	
RENAME	Allows commands to be renamed	0	
RESTACK	Selectively keeps search statements	0	
RESTART	Clears all previous commands and search statements	0	
Search statement*****	Retrieves records from file	93123	43
SENSEARCH	Searches text of a retrieved set for a word or phrase in same sentence	103	0
STOP****	Terminates search session	6236	3
STORESEARCH	Initiates process of storing user search	0	
STRINGSEARCH	Searches all text of a retrieved set for a given word or phrase	225	*
SUBHEADINGS APPLY	Applies subheadings to search stmt.	505	*
TIME	Display cumulative search or connect time	340	0
TITLESEARCH	Searches all text of a retrieved set for a given word or phrase	6301	3
TREE	Displays hierarchical position of term in MeSH structure	112	*
USERS	Tells number of users logged onto system	94	*
VERSION	Changes form of program message (short, long)	0	
YES	Response to many program messages	47858	22
Total		215886	100

*Less than 1%.

**Parser determined that session was disconnected before logout was completed. Not an ELHILL command.

***Number of responses given by multimeaning program response. Not an ELHILL command.

****Of these, 3433 were STOP YES commands.

*****Frequency of use of FIND command included in search statement.

TABLE 3. Use of operators and options in search statement.

Name of Operators and/or options	Number of Occurrences	Mean Number of Occurrences in Search Stmt.	Percent Distribution of Number of Operators in Single Search Stmt.			
			1	2	3	>3
AND	48,786	.52	82	13	4	1
OR	26,693	.29	58	25	10	7
NOT	3,764	.04	93	5	1	1
FROM-TO	94	.001	100			
LESS THAN	19	.0002	100			
GREATER THAN	49	.0005	100			
ALL	14,256	.15	69	22	8	1
STAR	4,660	.05	80	15	4	1
EXPLODE	9,392	.10	87	12	1	
Global category	4,075	.04	100			
qualifiers						
Category Qualifiers	1,765	.02	100			

In the sample of searches 48% of the search statements used one search term, 39% used two, and the remainder (13%) included three or more search terms in a single statement. The average number of terms in a search statement was 1.9.

Search statements have set numbers associated with them and when records are retrieved they are assigned the set number of the search statement. That set number can be used in subsequent search statements to further refine the search results. An average of 2.3 set numbers were used in each search statement. Fifty-one percent of the statements had one search statement number in them, 32% had two, and the remainder had three or more.

Table 3 summarizes the extent to which various operators and options are used in search statements. In 93,123 search statements there were 48,786 AND operators used. For every two search statements there was roughly one AND operator. Eighty-two percent of the search statements that had AND operators in them had only one such operator and 18% had more than one.

The OR operator occurred approximately once for every three search statements, and more frequently in a single search statement than the AND operator. The NOT, FROM-TO, LESS-THAN, and GREATER-THAN operators were quite infrequently used in the sample.

Category qualifiers are two letter mnemonics used to identify each element of a record in the ELHILL database. The mnemonics "ab" for abstract, "au" for author, and "ti" for title are examples of category qualifiers. In a search statement they can either be embedded in the statement or precede it. A category qualifier that precedes all search terms is global, that is it applies to all succeeding terms. There were 4075 global and 1765 regular qualifiers used in the searches.

The Print Command

Once retrieved, citations can be printed. The PRINT command is not as complex in syntax as the search statement, but does contain a number of options. The user may request a specific number of citations printed; some citations may be skipped; category qualifiers may be used to

TABLE 4. Usage of print parameters and print commands.

Print Parameter/ Constant Name	Print Parameter Code	Frequency of Occurrence	Percent Distribution
Compressed		5873	41
Full	FU	3259	23
Detailed	DL	2050	14
Author, Title, Abstract, Source	AR	1282	9
Indented		404	3
Complete		330	2
Standard	SD	103	1
All others		253	2
Total		13554	99

limit the elements of a record printed; a search statement number may be specified; and the format in which the records are displayed can be controlled.

The PRINT command can print the entire contents of a retrieved set, stopping after a certain number of lines have been displayed, or the user can specify the number of items to be printed. Approximately 60% of the time the user simply requested an entire set be displayed. When a print request count was specified, the average number was 5.4. Forty-seven percent of all these requests were for a single item, and 80% were for one to five items. Roughly a third of all print statements contained a request for the number of items to print.

Only 16% of all print statements requested that some records be skipped before others were printed. The most frequently occurring number to skip were between 5 and 6 items. The frequency of use of a search statement number in a PRINT command was also low—only 5% of the commands had them, but half of the print statements incorporated category qualifiers.

Print constants are used to format output in many different ways. Forty percent of all print statements used these constants, and in 15% of all the print statements more than one was used. Table 4 lists those that were used most frequently. Forty-three percent of the usages were accounted for by a single constant-compressed print. A large number of parameters (20 more than appear in Table 4), many of which are unique to printing a particular file, are rarely used.

Program Responses

The pattern of an online search is that a user enters a command or search statement, the program issues a response to the user command, and then the program issues a cue message prompting the user for the next command or search statement.

Most responses that are issued by ELHILL are composed of a series of individual messages joined together and tailored to the particular situation. An example of this occurs where the user changes to another file to search. The ELHILL message is:

You are now connected to the <filename> file.
SS <integer>/C?

There are two components to the message, the "You are now ..." component, and the "SS <integer> ..." component. Tables 5-8 summarize the frequencies for each component of a response. There is some incompatibility between these tables and Table 2. Tables 5-8 display the frequency of occurrence of message components, not entire messages. What appears to the user as one message is in fact a series of components.

Table 5 summarizes the frequency of various types of messages issued by the ELHILL system. Informational messages defined as messages which give the user the

TABLE 5. Frequency of message types issues by the ELHILL system.

Type of Message	Frequency of Occurrence	Percent Distribution
Informational	158817	61
Cue	42640	16
Error	3440	1
System	96	*
Text	54747	21
Total	259740	99

*Less than 1%.

TABLE 6. Ranked list of informatory messages issued by the ELHILL system.

Message title or text	Message description	Frequency of Occurrence	Percent Distribution
Postings message	Number of postings found for the search statement	76475	48
No postings message	No postings were found for the search	20031	13
'time ovflw. cont? (y/n) user:'	More time required to complete request. Ask whether to continue search.	17877	11
Searched-Qualified Msg.	Informs user of no. of items searched and no. meeting criterion. Asks whether to continue search.	8354	5
'Hello from ELHILL...'	Logon message.	6759	4
'You are now connected to the <filename>'	Gives file currently available for searching	6272	4
'Good-bye'	Logoff message	6238	4
Multi-meaning msg.	Term entered has multiple meanings. User must select one.	5181	3
All other messages		11630	7
Total		158817	99

TABLE 7. Ranked list of cue messages issued by the ELHILL system.

Message title or text	Message description	Frequency of Occurrence	Percent Distribution
SS <integer>/C?	Prompt to enter a search statement or command	10029	24
'USER:'	A reprompt. Normally issued when a null line is entered.	5397	13
'Requestors' name, or same-user:'	Name of user to receive offline prints	3400	8
'Search title, or none-user:'	Title of search when offline prints requested	3263	8
'cnt <integer> user:'	Prompt to continue entering text that was not complete on one line.	2918	7
'Done? (yes/no) user:'	Asks whether session is finished.	2833	7
All other messages		14800	35
Total		42640	102

TABLE 8. Ranked list of error messages issued by the ELHILL system.

Message title or text	Message description	Frequency of Occurrence	Percent Distribution
'<token> is not a valid print parameter'	Invalid print parameter used	925	27
'Bye bye.. your user code is not known to ELHILL'	Invalid user logon name used	536	16
'Password is incorrect. Please enter your password.'	Invalid password entered for logon name	323	9
'<token> is not a correct command name'	Invalid command name entered	233	7
'<token> is not a recognized database	Invalid data base name entered	182	5
'Storpgstg ovfl'	Insufficient system space to hold all postings retrieved	168	5
'You are already connected to the <filename>'	User requests file change to current file	151	4
'ssn has fewer postings than requested'	Print command called for more items printed than were in the set	122	4
'Gentrm ovfl'	Number of terms in search stmt. generated by EXPLODE or truncation exceeds ELHILL maximum	116	3
All other messages		684	20
Total		3440	100

status of a search request or command, comprise 61% of all messages issued. For example, one frequently occurring informational message reports the number of records or postings that satisfy a search statement. Another informational message is a greeting that appears when the user logs onto the ELHILL system.

Cue messages are the prompt that the user receives from the program. They indicate the program is ready for the user to enter a command or that the program needs further information. Sixteen percent of all messages issued were cue messages.

Many times the appropriate program response to a user command is to print citations. Twenty-one percent of all program responses were text responses, with the overwhelming percentage (99) of that occurring from a PRINT command.

Error messages are issued when the user makes a mistake or when the ELHILL program is unable to process a user request. Only 1% of all messages were error-related.* System messages are produced when the operations or programming staff enter control commands to start, stop, or test the system. These constitute a very small proportion of the total messages.

Table 6 presents a ranked list of the most frequent informational messages issued by the ELHILL system. Forty-eight percent of all informational messages were the postings messages. These are produced when the program

finds a set of records that meet the search statement requirements. The postings message includes a count of the number of postings found for the search statement. This value averaged 1137 postings for all the messages.

The second most frequent informational message is issued when no postings are found. Third in frequency is a time-overflow message, constituting 11% of all informational messages. The ELHILL system allocates a certain quantum of central processing unit (CPU) time to execute a search statement. If the statement requires more time, the process stops once the limit is reached and the user is asked whether the search statement should continue. As Table 2 indicates, users almost always answer YES.

The STRINGSEARCH and TITLESEARCH features of the ELHILL system allow the user to perform free text searching of words in the abstract or title of a bibliographic record. When a prescribed quantum of CPU time has elapsed, the searched-qualified message informs the user of the status of the command and asks the user whether to continue the search. At each issuance of the message, the number of items searched and the number meeting the qualifications are displayed. The average number of items searched was 214 and the number qualified was 65, a two-thirds reduction.

The most frequent cue message prompts the user to enter a search statement or a command (Table 7). The count of the number of search statement cue messages in Table 7 by no means reflects the total issued. This case is the most extreme example of counting only a segment of a message rather than a full message. In this case there were 10,029 instances of a search prompt alone. Many more such prompts occurred in combination with other messages. In

*This number probably understates the number of errors made by searchers. The flexibility of ELHILL allows any item entered to be considered a search term. Thus some errors may not be accurately counted by recording error message frequencies.

fact, every program response is followed by a cue. When viewed in this manner and excluding prompts by commands like OFFSEARCH for name and address, 88% of all messages were search statement cues and 11% asked the user whether to continue printing citations.

When the user enters a null line (no characters transmitted), the system reprompts with the word "USER": the second most frequent cue message.

As noted in Table 5, only 1% of all messages are error-related, a very small number indeed. In fact, only one error message was recorded for every two searches. Table 8 lists the most frequent errors. At the top of the list is an error related to the misuse or perhaps misspelling of a print parameter. Second and third on the list are errors related to the logon procedure, indicating that users have trouble entering their correct user code and password. The logon process is extremely troublesome for users. The original sample consisted of 7877 searches. Only 6759 of these resulted in a successful logon. Thus, 14% of the attempted logons failed.

Invalid commands and invalid database names are in fourth and fifth place, respectively.

Evaluation of System and Usage

The data presented in this article provide a description of the usage of the ELHILL system and a basis for evaluating both system characteristics and user behavior, including query language design, systems design, telecommunications, and training.

In the area of language design the frequency of various commands (Table 2) suggests several conclusions. The very nature of the search process means some commands will be heavily used (e.g., a search statement and a PRINT command), while other special-purpose commands will be needed in only a few cases. The language could be simplified by combining commands that perform the same function in slightly different contexts. String searching of all types could be performed with one command and an appropriate set of operators as part of the command.

Print parameters are one language feature that in this sample led to high rates of user errors. A large number of print parameters control the output format of search results. Some of these are unique to particular databases. Error analysis suggests that users are having trouble either spelling or selecting the appropriate print parameters. Consolidation and simplification of the number of options might be useful.

Several systems design problems surfaced in this analysis. One is capacity limitations placed on the user by the system. Another is within the user-system dialog. Many of the messages produced by the ELHILL program occur when the capacity of the ELHILL program itself is reached. Limits are placed on the number of postings that can be retrieved and the number of terms that can be generated by an EXPLODE command. When the system was originally developed these were no doubt real constraints, but with

dynamic storage allocation, a redesigned system could eliminate these limitations.

In the ELHILL system there are several situations where the search process is interrupted when the amount of processing time allocated to the user for a single function is exceeded. At this point the user is issued a cue message and asked whether the task should continue. Examples include time overflows during searching, the "searched-qualified" message when doing a title or string search, and the "DONE" message issued during logoff. The statistical evidence suggests that users' responses are dominated by "yes" answers indicating they want a process to continue or they do indeed want to log off. In one case alone, the time overflow message, 11% of all informational messages relate to this question. Less than 1% of all user responses were the word "no," while 22% were the word "yes." This suggests a high volume of traffic for a question that almost always seems to be answered in the affirmative. Based on this evidence, the system should be revised to conclude the operation without asking the user for intermediate confirmation to continue.

The evidence from the sample strongly suggests that users are having difficulty with the logon and logoff procedures. Evidence supporting this conclusion comes from a number of sources. The parsing program identified the existence of 7877 searches in the sample by means of locating a logon command, a logoff command, or intermediate search statements that identified a search in progress. Yet only 6759 welcome messages were issued by the system, indicating the successful initiation of a session. Thus, 14% of the attempted logon's failed. In addition, 323 invalid password messages were displayed, and 536 invalid user logon code messages were issued. It is difficult to determine the cause of the problem: Perhaps users type the user codes and passwords with such confidence that they make errors, or perhaps there are telecommunication difficulties. In any event, this seems to be a major problem and deserves further attention.

Evaluation of the search process could be improved by making changes in the way sessions are logged. Currently, only the first 57 characters of each line sent by the user and transmitted by the program are logged. Recording the full user and program text would ensure more accurate analysis of the search dialog.

The process of training users for the ELHILL system can be assumed to be excellent since only 1% of all messages issued by the system indicated errors. This finding is consistent with NLM's extensive training conducted by experts throughout the United States. The payoff is evident in the low error rates.

Conclusions

This article has analyzed features of the ELHILL query language used in a sample of 6759 searches conducted at the National Library of Medicine. The analysis covered the frequency of usage of each database, as well as the fre-

quency of usage of various commands and statements. Not surprisingly, the search statement and print command constituted 60% of command usage. A number of commands were not used at all and many were used only infrequently.

The search statement can employ binary, unary, and ranging operators to link search terms and search sets together. It can also employ category qualifiers and truncation codes. Roughly two search items were found in each search statement, and every other statement used the binary AND operator to link terms or sets. The OR operator was used in about every third statement. Ranging operators (e.g., FROM-TO) and the NOT operator were used infrequently.

Seventeen percent of all commands in the sample were PRINT statements and 60% of these requested displays of an entire search set. Compressed printing was the most requested format for displaying results.

Most of the messages (61%) issued by the ELHILL program informed the user of the status of a command or search statement. Twenty-one percent of the messages were text resulting from a PRINT statement.

The very low frequency of error messages, approximately 1% of all messages issued, indicates a high level of searcher expertise and quality training.

The data gathered in this analysis suggest several areas where query language and the system design can be improved. Some commands and some print parameters can be eliminated. Print parameters seem to cause user problems and consolidation of the numerous options might reduce confusion. Limitations placed on the capacity of ELHILL to handle large retrieved sets were realistic when the system was designed, but can probably now be removed. Finally, a large number of transactions are generated when the program asks the user whether to continue searching when a predetermined quantity of time has passed or continue printing when a predetermined number of citations have been displayed. Users overwhelmingly answer yes to these messages. If these were eliminated program functioning would be reduced and user searching made more efficient.

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