END USER TOUCH SEARCHING FOR CANCER THERAPY LITERATURE - A RULE BASED APPROACH

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Abstract

This paper reviews work towards building an expert system for searching the cancer therapy literature on MEDLINE. A modified subset of the Medical Subject Headings (MeSH) has been stored on a micro-computer and accessed via a touch terminal. Searches, previously requested of the Oncology Information Service at the University of Leeds, have been used to test out the principle of end user searching and the results compared with the searching expertise of a MEDLARS indexer. Original program development was in PASCAL, but a rule-based approach, which is independent of a particular programming language, has been developed for search term and frame selection adopting a 'blackboard' philosophy in tracing the process of selection. Work is progressing on an implementation using the expert systems programming language PROLOG, which has been found a very suitable language for representing rules and provides a ready made rule interpreter. It is suggested that this approach is superior in terms of retrieval performance compared with alternative approaches to end-user searching which fail to exhibit detailed knowledge regarding the subject matter of the search.

1. Introduction

The work described in this paper is the outcome of an investigation into the information sources used by doctors and consultants when treating patients suffering from cancer (ref.14). Whilst the investigation revealed significant problems in the use of patient record systems and the cancer registries as potential sources of useful information via a computer system and in addition brought to light differing views on what were regarded as vital or essential sources, it revealed a universally high regard for the published literature. Although information on major improvements in cancer therapy would be disseminated rapidly through informal channels often ahead of publication, sadly these advances are rare and in most cases treatment results are measured in terms of a percentage improvement in the five year survival rate. It could be suggested, however, that on-line literature searches were not being carried out as frequently as perhaps they should, and it seemed that much reliance was being placed on personal reprint/ photocopied collections of published articles which were claimed to be invaluable yet would have been built up in an ad hoc manner, be suspect in terms of coverage, have no index, be time-consuming to search and difficult to maintain (ref. 15). This investigation was made in the context of an available search service provided by the Oncology Information Service based at the University of Leeds, an internationally recognised information service on cancer. This service having been established to provide information to health professionals by the production of regular updating bulletins and the provision of online searches.

An earlier investigation by the author to evaluate the Cancerline database provided an opportunity to gain experience in the free text searching of Cancerline and controlled vocabulary searching of Medline on all topics relating to cancer (ref. 13). The conclusions of the evaluation included the recommendation that if a high recall was required then both databases should

be searched, but it was also clear that certain searches were more easily stated on Medline because of the sophisticated thesaurus (MeSH). On the whole searching Medline was easier given knowledge of the indexing vocabulary and searching techniques with term explosion facilities and the powerful application of sub-headings to qualify the controlled terms, both of these features having no equal on a free text searching system.

The low number of on-line literature searches on the topic of cancer therapy and the attractive notion of providing a means for doctors and consultants to perform their own searches were coupled to the growth in interest in expert systems to produce the idea of an easy to use searching system embodying the expertise of a human intermediary (ref. 16). This may seem to present conflicting design requirements yet an existing language framework has provided an appropriate means for translating user requests in a qualitative way.

2. An End User Interface based on MeSH

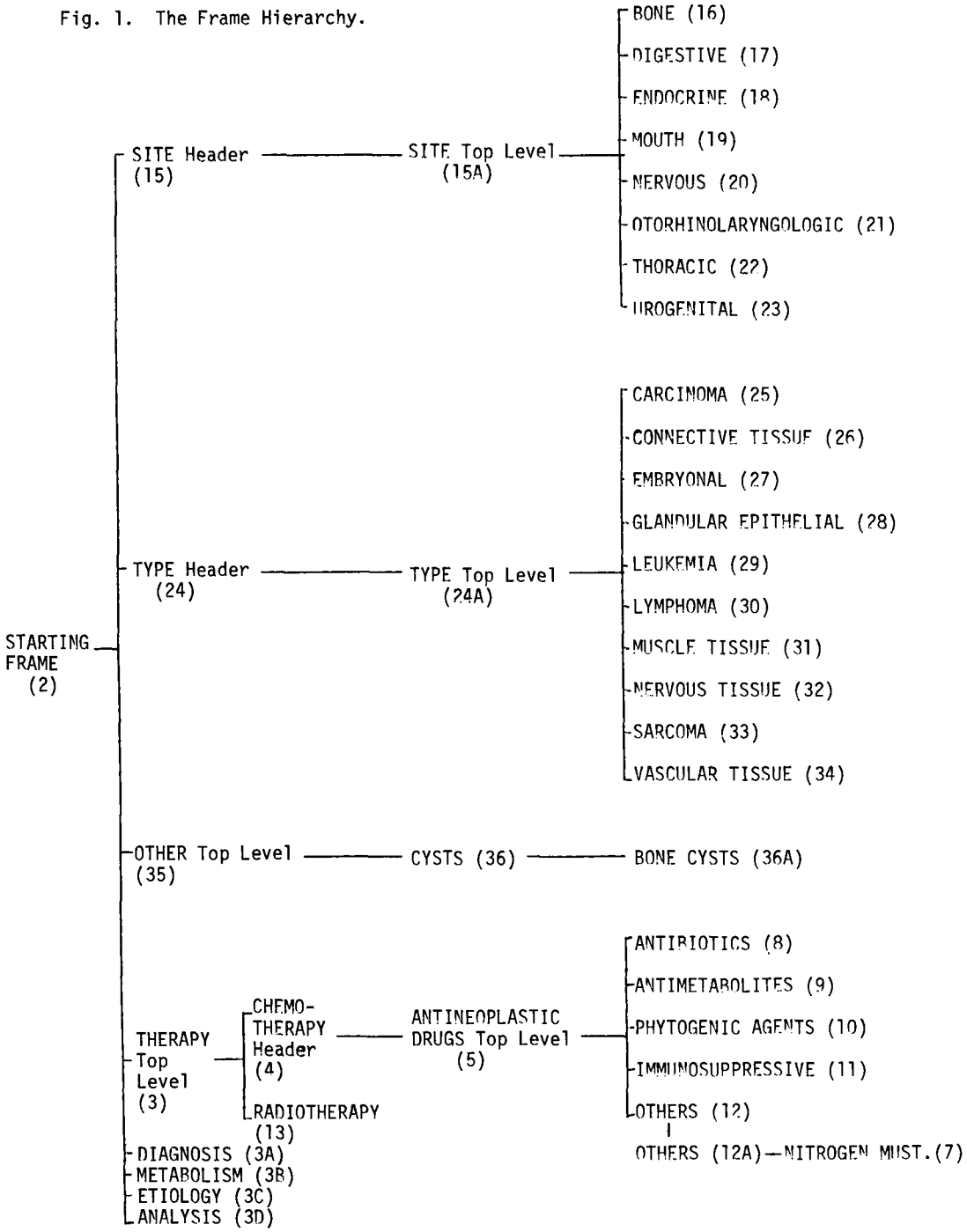
The easiest to use information systems are those that employ a menu. These systems constrain the dialogue and drive the system to a specific goal. The Medical Subject Headings (MeSH) used in the indexing of Medline have the potential to act as a menu. The major difference between a normal menu system and the system based on MeSH being the multiple term selection and the resulting multiple paths through the hierarchy. In addition MeSH needs to undergo some restructuring and certain features need to be incorporated which will help the user to specify the concepts involved in cancer therapy. For example, it is necessary to hide the use of sub-headings so as to present a uniform term selection procedure and to better indicate the meaning of a particular term when it refers to a less specific set of references than its name implies. The grouping of terms also needs to be modified so as to fit within the restrictions of a normal visual display unit by being factored into frames. To this end frames have been constructed using particular subsets of MeSH terms resulting in a frame hierarchy intended to be comprehensive with respect to the major concepts involved in cancer therapy (Fig.1.)
The use of MeSH overcomes the need to process the end-user description into the controlled volcabulary which is an important feature of the system, using the expertise of the end-user to translate his own natural language request, building in explanations where necessary. A total of 41 frames have been built into the hierarchy where the terms displayed on a particular frame are either high level terms that need expansion, end-terms for searching Medline or terms that would be translated into sub-headings for the modification of other terms and so on. The user may exhaust the search specification before the hierarchy is followed to the lowest frames, which in any case is down a maximum of seven levels and usually either three or four levels for each of the major concepts involved. It is appreciated that a deeper level of hierarchy may present an annoying interface with too many frames, experienced in some menu driven systems, however the parameters influencing the restructuring of MeSH have resulted in a shallow tree structure unlikely to be criticised for requiring too many selections and frame displays. The first frame of the hierarchy indicates the concepts which can be specified, if required:-

```
(ALL CANCERS)
     (CANCER AT A PARTICULAR SITE)
     (CANCER OF A PARTICULAR HISTOLOGIC TYPE)
     (OTHER)

(THERAPY)
(DIAGNOSIS)
(METABOLISM)
(ETIOLOGY)
(ANALYSIS)
```

All the terms on most subsequent frames have been put into strict alphabetic order within a frame with no inversion to collocate, e.g. MAST CELL SARCOMA rather than SARCOMA, MAST CELL:-

```
FRAME 33
                    (ALL SARCOMA)

(GENERAL SARCOMA)              (LIPOSARCOMA)
  (ANGIOSARCOMA)               (LYMPHANGIOSARCOMA)
  (CARCINOSARCOMA)             (LYMPHOSARCOMA)
  (CHONDROSARCOMA)             (MAST CELL SARCOMA)
  (CYTOSARCOMA PHYLLODES)      (MYOSARCOMA)
  (EWING'S SARCOMA)            (MYXOSARCOMA)
  (FIBROSARCOMA)               (OSTEOGENIC SARCOMA)
  (KAPOSI'S SARCOMA)           (RETICULUM CELL SARCOMA)
  (LEIOMYOSARCOMA)             (RHABDOMYOSARCOMA)
  (LEUCOSARCOMA)
```

Fig. 1. The Frame Hierarchy.



All concepts are normalised to terms including sub-headings, e.g.

```
FRAME 3

:
(FEVER THERAPY) - term
(NURSING)       - sub-heading to disease term
:
```

Terms with a common pre-co-ordination e.g. Site & NEOPLASMS are shortened to the site element of the term to give a less cluttered screen:-

```
FRAME 21

        (AS PRIMARY)/ (AS SECONDARY)
    (ALL OTORHINOLARYNGOLOGIC NEOPLASMS)
          (EAR)
          (LARYNGEAL)
          (NOSE)
             (NASOPHARNGEAL)
             (PARANASAL SINUS)
          (PHARYNGEAL)
          (TONSILLAR)
```

3. Touch Term Selection

The advantage of the presentation described in Section 2 is that the user need not type but has only to indicate a term using some mechanism. Indicating a term may cause it to be part of a search specification or lead on to more detailed specification. This overcomes one of the physical obstacles to online retrieval, the problem of having to type, which is a significant obstacle in medicine with such a rich vocabulary amply demonstrated by the first disease term in FRAME 21 above. Other approaches to the provision of end-user searching systems fail to address this particular problem (refs.4,8,10,11,12,19,21,22,24) A simple mechanism for term selection based on cursor movement was initially implemented (ref. 17) but this has since been replaced by being able to touch the required term to indicate selection.

Frames were constructed as straightforward text files using a full screen editor and programs were written in PASCAL which read the text files and generated formatted files with elements for storing the term, the X-Y location of the start of the term, the length of the term, a selection indicator and linking information to a further frame if necessary. The X-Y location of the start of the term and the length being necessary for subsequent translation of the X-Y co-ordinate pair sent by the touch terminal when touched by the end user. The use of formatted records took the particular micro-computer system used in this initial development to the limits of its storage capacity and limited the extension of the hierarchy to include extra frames without first carrying out a significant exercise in data compression. Nevertheless it enabled a first SELECT program to be written which exhibited the major features of touch-term selection, and deselection, by cursor movement and then by straightforward touch. With this limited but effective demonstration it was possible to evaluate the potential of the approach of using a specially modified sub-set of MeSH against the searching expertise of a MEDLARS indexer. This was carried out using genuine searches requested of the Oncology Information Service. The results of this search comparison are presented in Fig.2 and show that the idea worked well enough to encourage further work on formalising the workings of the interface. It was recognised early in the project that to embed the complete knowledge and experience of an indexer into the intermediary system would not be appropriate as this would readily demonstrate the law of diminishing returns, instead the aim of the project would be to build a system that was able to comprehensively tackle a high proportion of searches (say 90%) but which would refer the searchers to a higher, human, authority for the small proportion of more difficult searches or where the user was experiencing difficulty in using the intermediary system.

4. Problems and limitations of the original program development

The exhaustion of disk space on the micro-computer being used (an Apple II with two 128K byte capacity floppy disk drives) could easily have been overcome by the purchase of a Winchester disk drive but provided a useful delaying mechanism, forcing a review of the programming methodology. The programming techniques adopted using PASCAL were typical, using stacks to establish which frames were to be visited and a trace of the frames visited to allow backtracking to take place, the

TITLE OF SEARCH	SEARCH STATEMENTS ON MEDLINE (M: MEDLARS INDEXER; I: INTERMEDIARY SYSTEM)	RESULT
1. Mixed Salivary Gland Neoplasms of the Tongue.	M: TONGUE NEOPLASMS AND MIXED SALIVARY GLAND TUMOR I: "	SAME
2. Treatment of Superficial Bladder Cancer.	M: SUBS APPLY TH,DH,DT,NU,PC,RT,SU,,RH BLADDER NEOPLASMS I: "	SAME
3. Surgery of Pulmonary Lymphoma.	M: EXP LYMPHOMA/SU AND EXP LUNG NEOPLASMS/SU I: EXP LYMPHOMA/SU AND EXP LUNG NEOPLASMS/SU AND NEOPLASMS, MULTIPLE PRIMARY	Reduced RECALL by I:
4. Recurrence of Cervix Neoplasms after Hysterectomy.	M: EXP CERVIX NEOPLASMS/SU AND EXP HYSTERECTOMY AND NEOPLASM RECURRENCE, LOCAL I: EXP CERVIX NEOPLASMS/SU AND NEOPLASM RECURRENCE, LOCAL	M: More PRECISE No surgery terms on I:
5. Adrenal Cortex Neoplasms in Childhood - Genetic Features.	M: 1. ADRENAL CORTEX NEOPLASMS/FG 2. 1 AND INFANT, NEWBORN OR 1 AND INFANT OR 1 AND CHILD, PRESCHOOL OR 1 AND CHILD I: ADRENAL CORTEX NEOPLASMS/FG	M: More PRECISE No child terms on I:
6. Psychological Ill-Effects of Cerebral Irradiation in Young Children(12)	M: 1. EXP BRAIN NEOPLASMS/RT 2. PSYCHOLOGY OR EXP RADIOTHERAPY/PX OR EXP BRAIN NEOPLASMS/PX 3. 1 AND 2 4. 3 AND INFANT, NEWBORN OR 3 AND INFANT OR 3 AND CHILD, PRESCHOOL OR 3 AND CHILD I: 1. EXP BRAIN NEOPLASMS/SC OR EXP BRAIN NEOPLASMS/CO OR MENINGEAL NEOPLASMS/SC OR MENINGEAL NEOPLASMS/CO 2. EXP BRAIN NEOPLASMS/RT OR EXP BRAIN NEOPLASMS/PC OR MENINGEAL NEOPLASMS/RT OR MENINGEAL NEOPLASMS/PC 3. EXP LEUKEMIA/RT OR EXP LEUKEMIA/PC OR EXP LYMPHOMA/PC 4. 1 AND 2 AND 3	M: Less RECALL M: More PRECISE A difficult search for both to specify.

Fig 2. Comparison of Search Statement Generation

switching of boolean flags held against each term on the formatted record for the frame to indicate selection and deselection and to act as the memory of selections. Unfortunately these mechanisms resulted in a complex situation in terms of further program development. In particular the need to be able to incorporate the 'knowledge' to translate the selections into valid search statements although it had been possible to review the selections manually and determine the appropriate search statements (see Fig. 2).

One major problem was the lack of a meaningful representation of the progress of the search, a stack of frame numbers does not convey how far a search has progressed and fails to indicate the reason for the need to visit that frame, a more explanatory mechanism was required. A second problem was in the choice of memory regarding which frames had been selected and which relied on an indicator on the formatted record for a particular frame. It was intended that the same frames could be used for specifying both primary and secondary sites of cancer by including a qualifying term at the head of the frame (see FRAME 21). To represent the search using the mechanism described which referred to both primary and secondary cancers would have necessitated a duplicate set of frames or an amendment to the formatted records which would have increased the complexity of the system. The programs provided a good demonstration but were unsuitable for further extension, in particular there was no formal method

for representing the knowledge of the indexer other than in the choice of terms for selection and a translation to recognised terms, sub-headings or term/sub-heading combinations. Developments in expert systems were being reviewed and it was seen that a rule-based approach could provide the answer to both the problem of meaningful representation and the handling of a 'memory'.

5. A Rule-based Approach

There is extensive literature on the use of production rules in the construction of expert systems (ref.1, 3, 5, 18) and it was the concept of a blackboard (ref. 6, 20) to be consulted by the various elements of an expert system that led to the eventual adoption of a rule-based approach for this particular application.

"If..Then" rules were written without regard to the eventual implementation language and went through several forms of syntax modification until the testing and actions required in the system seemed to be efficiently represented. The control of rule execution relies on a 'rule-context' which defines the ordered rule set which determines the progress of the dialogue at that particular stage. There are four main types of context, one concerned with the selection of frames, one with processing the results of term selection, one with generating valid search statements and one with handling the interaction with MEDLINE although these can be extended as required.

5.1. The Blackboard

The central feature of the system is the 'blackboard' (Fig. 3) which is divided into sections or boards which are consulted and updated by rules. This is equivalent to the patient database in MYCIN and acts as a record of data captured during the course of the dialogue with the end user. There may be a requirement for additional boards in the further extension of the system. The role of the blackboard is illustrated by a trace of the contents of the different boards when the system is accepting user selections to specify a search on "Primary Cancer of the Liver (Hepatoma) spreading to the heart, treated with Methotrexate" - a contrived subject. The trace takes the system to the point at which the statement generator context would be entered, which would be expected to generate the following statements:

```
SUBS APPLY DT
1. LIVER NEOPLASMS
2. HEART NEOPLASMS/SC
3. HEPATOMA
4. 1 AND 2 AND 3
SUBS CANCEL
5. METHOTREXATE
6. 4 AND 5
```

or some equivalent.

5.2. The Rules

The syntax and workings of the rules are best seen by example. The first rules are concerned with frame selection context, i.e. MASTERSELECT context:

```
RULE No.
1.  IF "START" ON CONTROL-BOARD
    THEN ERASE "START" FROM CONTROL-BOARD
         CLEAN SITE-BOARD
         CLEAN TYPE-BOARD
         CLEAN THERAPY-BOARD
         DISPLAY FRAME 2
         CONTEXT FRAME 2
```

(Note: IF "term" - tests the contents of a particular board

DISPLAY is a procedure which presents a frame of terms to a user.

CONTEXT changes the rule set to be consulted when term selection has been completed.

other procedures are self-explanatory).

```
2.  IF "SITE-TO-SPECIFY" ON SITE-BOARD
    THEN ERASE "SITE-TO-SPECIFY FROM SITE-
                                        BOARD
         DISPLAY FRAME15
         CONTEXT FRAME15

3.  IF "PRIMARY & term-to-expand & EXPAND ON
                                        SITE-BOARD
    THEN ERASE term-to-expand FROM SITE-BOARD
         DISPLAY next-frame
         SELECT (AS PRIMARY)
         CONTEXT next-frame
```

(Note: term-to-expand acts as a variable in normal programming and provides a general, repeatable rule feature, keeping the overall number of rules to a reasonable number.

SELECT acts on the screen by selecting one of the displayed terms indicated by inverting the display. This is done prior to entering the new context of rules)

The MASTERSELECT context has nine rules which are able to exhaust the complete frame hierarchy.

The following illustrates typical rules in the user selection context e.g.

FRAME24A context

Rule No.

1. IF (CARCINOID TUMOR)
   THEN DESELECT (CARCINOID TUMOR)
   WRITE (CARCINOID TUMOR) TO TYPE-BOARD

(Note: IF (term) refers to whether a term has been selected by a user.

DESELECT prevents repeated execution of a rule when the controlling mechanism dictates that rules which fire are retested, this mechanism depends on the presence of general rules which refer to variables which may be matched more than once.)

CONTROL-BOARD	SITE-BOARD	TYPE-BOARD	THERAPY-BOARD
"START"			
	"SITE-TO-SPECIFY"	"TYPE-TO-SPECIFY"	"THERAPY-TO-SPECIFY"
	"PRIMARY" "SECONDARY"	"	"
	"SECONDARY" "PRIMARY DIGESTIVE SYSTEM EXPAND FRAME17"	"	"
	"SECONDARY" "LIVER NEOPLASMS"	"	"
	"LIVER NEOPLASMS" "SECONDARY THORACIC FRAME22"	"	"
	"LIVER NEOPLASMS" "HEART NEOPLASMS/SC"	"	"
	"	"GLANDULAR EPITHELIAL EXPAND FRAME28"	"
	"	"HEPATOMA"	"
	"	"	"CHEMOTHERAPY EXPAND FRAME4" "DRUG THERAPY"
	"	"	"DRUG THERAPY" "PARTICULAR DRUG EXPAND FRAME15"
	"	"	"DRUG THERAPY" "ANTIMETABOLITES EXPAND FRAME9"
	"LIVER NEOPLASMS" "HEART NEOPLASMS/SC"	"HEPATOMA"	"DRUG THERAPY" "METHOTREXATE"

Fig. 3. The Blackboard.

6. IF term-to-expand
   THEN WRITE term-to-expand & "EXPAND" &
        next-frame to TYPE-BOARD
      DESELECT term-to-expand

7. IF TRUE
   THEN CONTEXT MASTERSELECT

(Note: TRUE ensures the rule will always fire and is the last rule of any context.)

This frame is exhausted by seven rules but displays some 15 concepts.

The system can be seen to be data rather than goal driven, taking data from both boards and frames as appropriate. The rule-based approach seems to provide a flexible and powerful means of programming the interaction without the explicit linking of individual rules found elsewhere, although it is expected that explicit linking may be necessary in interacting with MEDLINE, the boards will be used to make program construction modular and independent.

5.3. Implementation in PROLOG

There is considerable interest in the use of PROLOG for programming expert systems (ref. 2). The availability of a version of PROLOG running on a CP/M based micro-computer (ref. 9) has provided a means of investigating the implementation of the rule base in PROLOG with encouraging results. The predicate in PROLOG provides a straightforward way of implementing blackboards

e.g. Add (therapy-board ("DRUG-THERAPY"))
writes "DRUG-THERAPY" to the therapy board
Delete (therapy-board ("DRUG-THERAPY"))
cleans "DRUG-THERAPY" from therapy-board

Testing the contents of boards is achieved by stating the predicate in a clause

e.g. therapy-board(x)

where if anything has been written to the board the clause will evaluate to TRUE and the variable x will be instantiated to the value on the board. Specific testing of terms is similarly achieved

e.g. therapy-board ("DRUG-TO-SPECIFY")

which evaluates to true if that term is on the THERAPY-BOARD.

The coding of the rules described in section 5.2 is achieved in a direct way:-

e.g. Rule 1 in the MASTERSELECT Context

```
master-select() if control-board ("START") &
            Delete((control-board("START")))
                   & clean(site-board)
                   & clean(type-board
                   & clean(therapy-board)
                   & display(frame2) & select()
                   & context(frame2)
                   & master-select()
```

as each predicate is evaluated to TRUE the next is tested until eventually tail-end recursion causes further rules from the same context to be tested. If one of the predicates FAILS - backtracking occurs and alternative matching predicates are tested. Predicates may cause side-effects to occur when being evaluated which is the way input and output is achieved e.g. display() and select() these predicates always evaluate to TRUE. There are no rule numbers so rule 2 in the MASTERSELECT context is represented by:-

```
master-select() if site-board(x "SITE-TO-SPECIFY"
                                        y)
          & Delete(site-board(x "SITE-TO-SPECIFY"
                                        y))
          & display(frame15) & select()
          & context(frame15)
          & master-select()
```

If the control board does not contain "START" (deleted after rule 1 has fired) then the first rule in MASTERSELECT will fail and the second rule will be tested and so on in respect of the contents of blackboards and selections. The following illustrates the rules applied after selection from frame 15 in the FRAME15 context:-

```
frame15() if selected(z) & Not(processed(z))
             & z EQ "PRIMARY SITE"
             & Add((processed(z)))
             & Add((site-board(0 "PRIMARY" 0)))
             & frame15()

frame15() if selected(z) & Not(processed(z))
             & z EQ "SECONDARY SITE"
             & Add((processed(z)))
             & Add((site-board(0 "SECONDARY" 0)))
             & frame15()
```

6. Conclusion.

Work on programming the expert intermediary system is continuing in between normal teaching commitments, nevertheless what has been achieved suggests that the approach is valid and offers an extremely powerful facility for the eventual use by the cancer treatment specialists directly. The true test may eventually measure the success or otherwise of the indexing effort in generating and updating MEDLINE. The ability to incorporate feedback, again with a minimum of user typing, has yet to be investigated although the outline design of a number of potential facilities has been completed. These facilities include the limitation by journal title using a list of the "top-ten" cancer therapy journals complemented by the retrieval results for each journal.

It remains to be seen whether work in this area will result in more searches being performed. From reactions sought so far it would appear that this may be likely. If the system is to be used on a regular basis then the quality of retrieval is all important and hence the need for an expert intermediary system.

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Needless to say any mistakes in the paper are attributable to me alone.

References.

1. Anderson R.H. The Use of Production Systems in RITA to Construct Personal Computer Agents. SIGART Newsletter. Vol 63 pp 23-28 1977.

2. Clocksin W.F., Mellish C.S. Programming in Prolog. Springer Verlag. Berlin 1981.

3. Davis R. King J. An Overview of Production Systems. Machine Intelligence Vol 8 pp 300-332 1977.

4. Doszkocs T.E., Rapp B.A. Searching Medline in English: A prototype user interface with natural language query, ranked output and relevance feedback. Proc. ASIS Annu. Meet. Vol 16 pp 131-137 1979.

5. Fain J. Programming in ROSIE: An Introduction by means of examples. Rand Note N-1646-ARPA Feb. 1982.

6. Feigenbaum E.A., Barr A. The Crysalis Architecture: The Blackboard. in The Handbook of Artificial Intelligence Vol II Pitman Books Ltd. 1982.

7. Guida G. Tasso C. IR-NLI:An Expert Natural Language Interface to Online Databases. Conference on Applied Natural Language Processing. Santa Monica, California. Feb. 1-3 1983.

8. Horowitz G.L., Bleich M.D. Paperchase: A computer program to search the medical literature. The New England Journal of Medicine. 305(16) pp 925-930 Oct. 1981.

9. McCabe F. Micro-PROLOG Programmer's Reference Manual. Logic Programming Associates Ltd. 1981.

10. Marcus R.S. An Automated Expert Assistant for Information Retrieval. in The Information Community: An alliance for Progress. Proc. 44th. ASIS Annu. Meet. Vol 18 pp 270-273 1981.

11. Marcus R.S. Investigations of computer-aided document search strategies. MIT Report LIDS-R-1233 Sept. 1982.

12. Meadow C.T. The Computer as a Search Intermediary. Online Vol 3(3) pp 54-59 1979.

13. Pollitt A.S. CANCERLINE Evaluation Project. Final Report. British Library Research & Development Report No. 5377 1977.

14. Pollitt A.S. Information Retrieval for Cancer Therapy:Problems and Prospects. BCS '81. Information Technology for the Eighties. R.D. Parslow (Ed) Heyden & Son Ltd London 1981.

15. Pollitt A.S., Whitcombe A. Personal Reference Collections and Online Searching. Journal of Information Science. Vol 3 pp 35-38 1981.

16. Pollitt A.S. An Expert System as an Online Search Intermediary. 5th. Intl. Online Information Meeting pp 25-32 London Dec. 1981.

17. Pollitt A.S. A Search Statement Generator for Cancer Therapy Related Information Retrieval. 6th. Intl. Online Information Meeting.405-413 London Dec. 1983.

18. Shortliffe E.H. Computer Based Medical Consultations:MYCIN. Elsevier Computer Science Library Artificial Intelligence Series(2) 1976.

19. Toliver D. A Program for Machine-Mediated Searching. Information Processing & Management. pp 61-68 Vol 17(2) 1981.

20. Waterman D.A., Hayes-Roth F. An Investigation of Tools for Building Expert Systems. Rand Report R-2818-NSF. The Rand Corporation Santa Monica 1982.

21. Walker D.E. Natural Language Access Systems and the organisation and use of information. COLING '82 pp 407-412 J. Horecky (Ed) North Holland Pub. Co. Academia 1982.

22. Williams P.W. A new device to simplify online seaching and reduce costs. 2nd. National Online Meeting pp 503-514, Learned Information Medford N.J. 1981.

23. Winston P.H., Horn B.K.P. Expert Problem Solving using If-Then Rules. in LISP. Addison Wesley 1981.

24. Yip M. An Expert System for Document Retrieval. M.Sc. Thesis, MIT Feb. 1981.