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Network Database Representation of Medical Knowledge Production Rules: An Application to Pediatric Diagnosis

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Network Database Representation of Medical Knowledge Production Rules: An Application to Pediatric Diagnosis

Abstract
This thesis is a representation of a specific set of artificial intelligence production rules with the CODASYL database management system "SEED" available at the University of Pennsylvania. Among the advantages of this database representation over embedding the rule in a higher level language program are:

1. The database management system (DBMS) additionally performs commercial and information retrieval functions relating to the environment in which the artificial intelligence representation is made.

2. The end user interface is potentially friendly, permitting easy updates and queries using various standard data manipulation routines and higher level processors of the DBMS.

The application area chosen for this demonstration in a simple hospital information system covering medical diagnosis and the patient-doctor interface. Indicative preliminary decision rules for diagnosis of a certain class of pediatric ailments were obtained from Dr. B. Athreya of the Childrens' Hospital of Philadelphia (affiliated to the University of Pennsylvania). The assistance of Dr. Athreya is gratefully acknowledged. It is important to note that the clinical data used here is merely indicative and has been used purely as a model. The same is not intended to represent correct or incorrect handling of diagnostic situations.

Comments

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NETWORK DATABASE REPRESENTATION OF MEDICAL KNOWLEDGE PRODUCTION RULES

—an application to pediatric diagnosis

by

NAVENDU VASAVADA

PHILADELPHIA, PENNSYLVANIA
APRIL 1982
NETWORK DATABASE REPRESENTATION OF
MEDICAL KNOWLEDGE PRODUCTION RULES

an application to pediatric diagnosis

NAVENDU VASAVADA
PHILADELPHIA, PENNSYLVANIA
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A thesis presented to the Faculty Engineering and Applied Science of the University of Pennsylvania in partial fulfillment of the requirements for the degree of Master of Science in Engineering for graduate work in Computer and Information Science.

Rob Gerritsen
Thesis Advisor

Aravind K. Joshi
Chairman, Graduate Group in Computer and Information Science
This thesis is a representation of a specific set of artificial intelligence production rules with the CODASYL database management system "SEED" available at the University of Pennsylvania. Among the advantages of this database representation over embedding the rules in a higher level language program are:

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note that the clinical data used here is merely indicative and has been used purely as a model. The same is not intended to represent correct or incorrect handling of diagnostic situations.
The typical approaches to knowledge representation in common practice are:

1. Embedding the knowledge structure in a higher level programming language like LISP.

2. Building a database corresponding to the knowledge structure.

The two approaches have their respective merits and demerits in different knowledge scenarios and hence it is not easy to define criteria leading to the selection of one of the approaches as a "better" implementation strategy.

It is however clear that in applications where it becomes important to have a user friendly interface, one would have to work on extensive software development independent of the knowledge representation and processing for generating query responses. For instance, in adopting approach (1) as above, the same program (probably in LISP) could be extended to provide a user friendly interface tailored to a specific application. On the other hand, approach (2) could make use of the advantage that a good commercial DBMS already has the software geared up for a user friendly interface.
This thesis presents an implementation of knowledge representation using the SEED DBMS. SEED is a network DBMS based on the CODASYL model developed by International Database Systems Inc. of Philadelphia and is available on the computing facilities at the University of Pennsylvania.

The implementation is focused on a patient-doctor diagnosis model starting with a "commercial" database representing usual patient-doctor transactions and information (like patient and doctor information, visit and consultation schedules, billing and financial information relating to services performed, etc.). The same is extended to represent medical diagnosis knowledge so that a query can be made relating a specific entity in the database to diagnostic possibilities utilizing the knowledge subset of the database.

Some of the typical queries that the knowledge representation should respond to are of the form:

1. Given a specific patient, what are the diagnostic possibilities for him/her? The response to this query should utilize the information on the patient's history and outcomes of various diagnostic tests that the patient took. This query is responded to by using the knowledge representation in the database as well as patient
information.

2. What are the diagnostic possibilities that can be detected by a particular diagnostic test? Conversely, what are the diagnostic tests (and their corresponding outcomes) that lead to a given diagnostic possibility? Response to this query could be useful at the time when the patient is in consultation with a doctor and is in the process of having diagnostic tests ordered by the doctor.

An example of a similar situation where the integration of a "knowledge" database with a commercial database could have powerful utility are is a manufacturing processes application integrating material testing, quality control and process control rules with the same database containing information on components and materials.

A more imaginative version might extend a sales information database to integrate marketing strategy knowledge.
ELABORATION OF THE DOCTOR-PATIENT MODEL AND SOFTWARE DESIGN

OBJECTIVES

One cannot claim that medical knowledge today is completely structured. While we do have computer programs that analyse diagnostic tests solely relying on knowledge representation probably as well or better than most doctors, it seems unreasonable to imagine that the health care system in the near future could be fully automated. Computer technology relying on structured human knowledge is not a likely substitute for a human doctor within the present state of art.

It is intended to design software to respond to the queries elaborated in the earlier section. Specifically, the system should provide a report of diagnostic possibilities for a particular patient based on the knowledge represented in the database. A computer program can quickly scan the entire knowledge base as represented, thus assisting the doctor in his decision making process. However, a computer program cannot bring out aspects of medical knowledge that are unstructured in a doctor's decision making process and therefore not included in the knowledge base.

While the diagnosis and treatment of a patient in the present health care system is primarily the responsibility of a qualified doctor, the medical profession seems to have realised the boundedness of human rationality and memory as
well as the limitations on the human capability to process voluminous information. Probably as a consequence of this, current medical literature has good documentation of various systems, procedures, rules and policies for treatment that could be viewed as "structured" knowledge.

The provisional diagnostic tables constructed at the Childrens' Hospital of Philadelphia affiliated to the University of Pennsylvania for a certain class of diseases known as Monoarticular Arthritis of a Single Joint is the choice of the medical knowledge base for implementation. The same is presented in Annexure I.

It needs to be emphasised that the provisional tables in Annexure I chosen for this study are user purely as a test model. The tables do not bear a seal of official approval (say from the American Medical Association) and are not intended to represent correct or incorrect handling of diagnostic situations.

The data could well have been input as arbitrary alphanumeric characters at the expense of obtaining corresponding dummy answers to queries that might not make very interesting reading.
SCHEMA DESIGN CONSIDERATIONS

The CODASYL database diagram incorporating the schema design is presented in Annexure II. The database is divided into two areas: CLINIC and LABORATORY. Records relating to commercial database functions are assigned to the area CLINIC and those relating to "knowledge" to the area LABORATORY. The area specification for a record in CODASYL database terminology denotes its hardware location.

The records contained in the area CLINIC typifies the "commercial" database containing doctor-patient transaction information with just two entities and an intersection record - the patient, the doctor and the relationship between them. This could be greatly extended to incorporate most of the transactions in a major hospital.

The records in the area LABORATORY constitute the "knowledge" database. The entities are the various laboratory tests, their corresponding outcomes and inferences therefrom.

Entities

Area CLINIC - PATIENT, DOCTOR.

Area LABORATORY - TEST, TEST-OUTCOME, POSSIBILITIES

The PATIENT record contains an item
PATIENT-FINAL-DIAGNOSIS presumably to be entered by the doctor after the diagnosis has been narrowed down and treatment for the same is in progress.

Relationships

PATIENT : DOCTOR - Many to many relationship. One patient can consult with many doctors and one doctor can see many patients. The Intersection record is DOCTOR-PATIENT.

DOCTOR-PATIENT : TEST - Many to many relationship. Each DOCTOR-PATIENT transaction can lead to many tests and vice versa. The intersection record is TESTS-ORDERED. This intersection record has items OUTCOME-NAME and OUTCOME-CODE items to be entered after the test results have been received. Thus a patient is identified with the tests taken and the results obtained. It is with this prior information that corresponding diagnostic possibilities are searched from the "knowledge" subset of the database.

TEST : TEST-OUTCOME - One to many relationship. Test outcomes are discrete and unique. One specific outcome corresponds only to one test.
TEST-OUTCOME : POSSIBILITIES - Many to many relationship. For every test outcome there could be many diagnostic possibilities, and one possibility might be inferred from several test outcomes. The intersection record is TEST-LINE-ITEM, each occurrence of which is a unique knowledge production rule relating a diagnostic possibility to a test outcome and vice versa.
THE DIAGNOSTIC PROCESS

With user acceptability in perspective, the system is designed to parallel the doctor’s decision making process where the following sequence of steps is typical:

After consulting with the patient and performing preliminary examinations, the doctor narrows down the diagnostic possibilities solely on the basis of observable symptoms;

Diagnostic tests are usually ordered to verify and identify the possibilities;

A patient record is created or updated to contain his history. A record of tests ordered for the patient is also maintained.

When the results of the diagnostic tests arrive from the laboratory, the outcome is noted in the patient record. The doctor uses his knowledge, memory, books, tables (and, as suggested in the next paragraph, looks up the computer suggested diagnostic possibilities) to narrow down the choices to a few (perhaps one) diagnosis.

Using the SEED system designed here, the doctor could follow a similar sequence:
Display tests that can be ordered (using the high level processor HARVEST).

Store patient information and tests ordered for the patient in question in the records PATIENT and TESTS-ORDERED respectively (using the higher level processor GARDEN)

Store the test outcome when the results arrive in the record TESTS-ORDERED (again using GARDEN)

Execute the Data Manipulation Language program INTERN.FOR which suggests possible diagnoses for the patient in question indicating the basis of arriving at the same. The query implementation by INTERN.FOR is elaborated in the next section.

Store the final diagnosis for the patient in the PATIENT record if it is identified.

At any point in time, the doctor could make permissible queries using the higher level processor HARVEST, like those presented in ANNEXURE III.
QUERY IMPLEMENTATION BY DATA MANIPULATION LANGUAGE

The higher level processor HARVEST can respond to many sophisticated queries as presented in Annexure III in a very simple and user-friendly mode. In order to respond to the specific query asking for diagnostic possibilities for a particular patient and the basis thereof, it becomes necessary to write a SEED Data Manipulation Language (DML) program. The FORTRAN DML program INTERN.FOR utilises the SEED subroutines for data access and manipulation to achieve this purpose.

A listing of INTERN.FOR and the result of its execution are presented in Annexure IV.
Program logic for query implementation

The Data Manipulation Program INTERN.FOR (implemented in FORTRAN) uses the SEED FORTRAN DML subroutines made available to a FORTRAN program at run time for accessing elements in the database.

The program prompts for the patient code as input and proceeds along the following lines:

1. Retrieve the intersection records TEST-ORDERED linked to the patient. Each of these records contain data item OUTCOME-CODE corresponding to the TEST record which also owns it.

   It is presumed that when the test results arrive, the unique outcome code is entered into the TEST-ORDERED record. Before the test results are received, the OUTCOME-CODE is initialised to zero to indicate that the test results are awaited.

2. For all records where the OUTCOME-CODE is zero, a report indicating that test results are awaited is printed out.

3. For each of the remaining records, the OUTCOME-CODE is used as a key to retrieve the diagnostic possibilities corresponding to it. The diagnostic possibilities and the test outcome code
are pushed onto a stack. The array KPOS is the implementation of the stack with the variable LIST as the stack depth pointer.

4. When the push operation is complete, the stack is popped repeatedly to obtain a printout of each diagnostic possibility followed by the names of the tests and the outcomes (which are retrieved from the database).

The order in which elements are popped from the stack is determined by ranking each diagnostic possibility by the number of times it is indicated by corresponding test outcomes. Diagnostic possibilities indicated by identical test outcomes are grouped together.

A single diagnostic possibility can be indicated by several test outcomes. The elements pushed onto the stack in step (3) are the test outcome/diagnostic possibility pairs, with each test outcome having several corresponding diagnostic possibilities. In step (4), the stack is popped to "invert" the relationship and give diagnostic possibility/test-outcome pairs which are used to print the diagnostic report for the patient as in Annexure IV.
DISCUSSION AND FOLLOW UP WITH DOCTORS

The implementation of the knowledge structure in Annexure I in the CODASYL schema of Annexure II demonstrates that a DBMS can be effectively used in the application of Artificial Intelligence techniques.

In the narrower context of medical diagnostic decision making, it is demonstrated that a reasonably user-friendly system can be implemented using SEED and its higher level processors for implementing queries in easy English-like syntax.

The diagnostic possibilities report of Annexure IV for sample cases was shown to practicing pediatric physicians. The comments received in response are as follows:

1. The report is a ready reference exhaustive condensation of diagnostic possibility-test outcome pairs and thus ensures that the physician does not forget one or more possible inferences. An expert physician in unlikely to benefit from it as much as novice physicians. The system can provide structure in the learning process and thus serve as a useful educational aid.

2. The ranking of diagnostic possibilities by the number of times they are indicated by specific
test outcomes is not likely to form the primary basis for determining the final diagnosis. It is often the case that some diagnostic possibilities indicated fewer times dominate others. More knowledge rules need to be added to those in Annexure I in order to reflect this. However, structured knowledge rules for all exceptions of this type can be difficult to define.

3. Extending the point made above, there can be instances where a given diagnostic possibility-test outcome inference pair may be invalid when another specific diagnostic possibility is indicated by other test outcomes. It is recognised that the preliminary diagnostic table of Annexure I needs to be extended to incorporate more medical knowledge, some of which may not be structured. Inability to incorporate unstructured knowledge could limit the usefulness of the diagnostic report (as in Annexure IV) in real life diagnostic situations. Inductive jumps in diagnosis made by experienced physicians would be difficult to translate into structured rules.

4. Some physicians expressed fears that wrong inferences could result from incorrect test-outcome inputs (possibly due to human error).
5. Diagnostic decision rules in most areas of medical practice are not unique and universal. Each physician tends to build a set of "personalised" knowledge over years of experience. The system must have the flexibility to accommodate variations and changes that can be made by user physicians. It is important to have a user friendly interface to incorporate these "knowledge updates and changes".

6. Consulting physicians are increasingly using mini-computers for practice related commercial data processing. A system providing the capability to represent personalised knowledge to assist in diagnosis decisions has potential for wide acceptance by the profession.

It emerges from the above comments that a system providing implementation of personalised knowledge rules in addition to commercial database management functions has high user acceptability potential as an educational and decision making aid.
DIRECTIONS FOR IMPROVING USER ACCEPTABILITY

The user acceptability of the system can be furthered by improvising along the lines suggested above by practicing physicians. The primary objective is to incorporate as much structured knowledge as is possible for query implementation and at the same time to permit easy updates to reflect personal approaches. The following extensions are suggested:

1. Provide a "RANK" or "PRIORITY" data item in each POSSIBILITY record. This could be the criteria for determining the relative order in which the diagnostic possibilities in the report of Annexure IV are presented. The report could highlight the key diagnostic possibility-test outcome pairs.

2. Provide an "INCOMPATIBLE-WITH" record owned by the POSSIBILITY record giving the other diagnostic possibilities with which a given diagnostic possibility is incompatible. The procedure for treating cases where incompatible diagnostic possibilities are encountered could be incorporated into the DML if it is globally applicable. Possibly, a warning message would be displayed bringing this to attention.
3. Provide an "OVERRIDES" record owned by the POSSIBILITY record containing possibility-test-outcome pairs that are overridden by a diagnostic possibility. This provides for cases where the indication of a given diagnostic possibility implies that certain other specific diagnostic possibility-test-outcome pairs are no longer valid. When such a case is encountered, the overridden items are suppressed in the diagnostic report or printed with a warning in a footnote.

4. Introduce a character string data item "REASONING" in the TEST-LINE-ITEM record (recall that this is the intersection record of POSSIBILITIES and TEST-OUTCOME). This would extend educational utility and provide on-line documentation of personalised knowledge.

The above strategies permit updates in the knowledge structure through higher level DBMS processors. The embedding of knowledge rules (as above) in an application program are thus avoided.
REFERENCES


## Annexure I

### Preliminary Diagnostic Tables - Monoarticular Arthritis

<table>
<thead>
<tr>
<th>Test</th>
<th>Value observed</th>
<th>Diagnostic possibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC Hemoglobin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than &lt;8 gm%</td>
<td></td>
<td>Leukemia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neuroblastoma</td>
</tr>
</tbody>
</table>

| Normal:          |                |                                               |
|                  | neonate:       | 11-20 gm%                                    |
|                  | infant:        | 10-15 gm%                                    |
|                  | child:         | 11-16 gm%                                    |
|                  |                | Trauma                                        |
|                  |                | mechanical derangements                       |
|                  | older children | M: 14-18 gm%                                 |
|                  | & adolescents  | F: 12-16 gm%                                 |
|                  | 8 to 11 gm%   | JRA                                            |
|                  |                | Infectious                                    |

<table>
<thead>
<tr>
<th>Total white cell count:</th>
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<th></th>
</tr>
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<tbody>
<tr>
<td>1 week</td>
<td>5000-21,000/cmm</td>
<td>Trauma</td>
</tr>
<tr>
<td>4 week</td>
<td>5000-19,500/cmm</td>
<td>mechanical derangement</td>
</tr>
<tr>
<td>6-12 months</td>
<td>6000-17,000/cmm</td>
<td>bone disease</td>
</tr>
<tr>
<td>2 yrs</td>
<td>6200-17,000/cmm</td>
<td>tumor of synovium</td>
</tr>
<tr>
<td>child/adult</td>
<td>4800-10,800/cmm</td>
<td></td>
</tr>
<tr>
<td>Increased over 10,800/cmm</td>
<td>&gt; 2 yrs</td>
<td>Infectious arthritis</td>
</tr>
<tr>
<td>over 15,000/cmm</td>
<td>&lt; 2 yrs</td>
<td>Leukemia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neuroblastoma</td>
</tr>
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<th>Lymphocytes</th>
<th>Normal</th>
<th>Increased</th>
<th>Leukemia</th>
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<tr>
<td>1 week</td>
<td>up to 8610</td>
<td>&gt; 8600</td>
<td></td>
</tr>
<tr>
<td>4 weeks</td>
<td>up to 10720</td>
<td>&gt;11,000</td>
<td></td>
</tr>
<tr>
<td>6-12 months</td>
<td>up to 10675</td>
<td>&gt;11,000</td>
<td></td>
</tr>
<tr>
<td>2 years</td>
<td>up to 1030</td>
<td>&gt;10,000</td>
<td></td>
</tr>
<tr>
<td>child/adult</td>
<td>up to 3240</td>
<td>&gt;3000</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Polymorphs</th>
<th>Normal</th>
<th>Increased</th>
<th>Infectious arthritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 week</td>
<td>up to 9450</td>
<td>&gt;10,000</td>
<td>Osteomyelitis</td>
</tr>
<tr>
<td>4 weeks</td>
<td>up to 6825</td>
<td>&gt;7,000</td>
<td>Cellulitis</td>
</tr>
<tr>
<td>6-12 months</td>
<td>up to 5600</td>
<td>&gt;5,600</td>
<td></td>
</tr>
<tr>
<td>2 years</td>
<td>up to 5510</td>
<td>&gt;5,600</td>
<td></td>
</tr>
<tr>
<td>child/adult</td>
<td>up to 6480</td>
<td>&gt;6,500</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polymorphs</th>
<th>Reduced Increased</th>
<th>Infectious arthritis</th>
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</thead>
<tbody>
<tr>
<td>1 week</td>
<td>up to 9450</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>4 weeks</td>
<td>up to 6825</td>
<td>&gt;7,000</td>
</tr>
<tr>
<td>6-12 months</td>
<td>up to 5600</td>
<td>&gt;5,600</td>
</tr>
<tr>
<td>2 years</td>
<td>up to 5510</td>
<td>&gt;5,600</td>
</tr>
<tr>
<td>child/adult</td>
<td>up to 6480</td>
<td>&gt;6,500</td>
</tr>
<tr>
<td>Platelets:</td>
<td>Normal</td>
<td>Infectious arthritis</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Neonate</td>
<td>150 - 390,000</td>
<td>&lt;150,000</td>
</tr>
<tr>
<td>Infant</td>
<td>200 - 473,000</td>
<td>&lt;200,000</td>
</tr>
<tr>
<td>Children</td>
<td>150,000 - 450,000</td>
<td>&lt;150,000</td>
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<th>Sedimentation Rate:</th>
<th>Normal</th>
<th>Infectious arthritis</th>
<th>Neuroblastoma</th>
<th>Leukemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wintrobe method:</td>
<td>&gt;15 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Westergren method:</td>
<td>male &gt;15 mm</td>
<td></td>
<td>neuroblastoma</td>
<td>leukemia</td>
</tr>
<tr>
<td></td>
<td>female &gt;20 mm</td>
<td></td>
<td></td>
<td></td>
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Normal <15 mm

trauma
mechanical de-
arrangements
bone disease
tumor of synovium
<table>
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<tr>
<th>Radiology</th>
<th>Compatible with diagnosis of-</th>
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<tbody>
<tr>
<td>Normal joints</td>
<td>early infectious arthritis</td>
</tr>
<tr>
<td>Normal bone</td>
<td>early JRA</td>
</tr>
<tr>
<td>Joint effusion</td>
<td>trauma</td>
</tr>
<tr>
<td></td>
<td>JRA</td>
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<td></td>
<td>infectious arthritis</td>
</tr>
<tr>
<td></td>
<td>bone disease with effusion</td>
</tr>
<tr>
<td></td>
<td>in adjacent joint</td>
</tr>
<tr>
<td></td>
<td>pigmented villonodular synovitis</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>JRA</td>
</tr>
<tr>
<td></td>
<td>hemophilia</td>
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<td>Erosions of joint</td>
<td>JRA</td>
</tr>
<tr>
<td></td>
<td>hemophilia</td>
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<td></td>
<td>infectious arthritis</td>
</tr>
<tr>
<td></td>
<td>aseptic necrosis</td>
</tr>
<tr>
<td>Lytic lesions/cysts</td>
<td>aseptic necrosis</td>
</tr>
<tr>
<td></td>
<td>bone tumors</td>
</tr>
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<td></td>
<td>leukemia</td>
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<td></td>
<td>neuroblastoma</td>
</tr>
<tr>
<td>Ankylosis</td>
<td>JRA</td>
</tr>
<tr>
<td></td>
<td>hemophilia</td>
</tr>
</tbody>
</table>

Bone scan:

- Increased uptake
  - infectious arthritis
  - JRA
  - hemophilia
  - aseptic necrosis (late)
  - tumors

- Reduced uptake
  - aseptic necrosis (early)
  - tumors
ANNEXURE I (contd)  page 4

**Arthroscopy:**

- Cartilage normal
- Meniscus normal
- Synovium normal
- Cruciate ligament normal

- Cartilage tear
- Meniscus tear
- Cruciate ligament tear

- Pannus formation
- Cartilage erosion

- Hyperiopthic synovium —

- Loose body in the joint —

**Arthrogram:**

- Meniscus tear
- Abnormalities of articular cartilage
- Tear of cruciate ligament

- Normal
- Traumatic arthritis
- Disease of bone close to joint

- Traumatic arthritis

- JRA
- Infectious arthritis
- Hemophilia

- JRA
- Infectious arthritis
- Pigmented villonodular synovitis
- Chondromatosis
- Synovial sarcoma
- Foreign body arthritis

- Trauma
- JRA

- Normal
- Traumatic arthritis
<table>
<thead>
<tr>
<th>Finding</th>
<th>Diagnosis</th>
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<tr>
<td>hyper trophy synovium</td>
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<td>synovial sarcoma</td>
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<td>negative</td>
<td>traumatic arthritis</td>
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<tr>
<td>blood culture</td>
<td>bone disease close to the joint</td>
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<td>skin culture</td>
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<td>infectious arthritis</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Finding</td>
<td>Diagnosis</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Blood culture</td>
<td>traumatic arthritis</td>
</tr>
<tr>
<td>Skin culture</td>
<td>foreign body arthritis</td>
</tr>
<tr>
<td>Rectal culture</td>
<td>mechanical derangement</td>
</tr>
<tr>
<td>Throat culture</td>
<td>hemophilia</td>
</tr>
<tr>
<td></td>
<td>infectious antibodies</td>
</tr>
<tr>
<td></td>
<td>JRA</td>
</tr>
<tr>
<td></td>
<td>bone disease close to the joint</td>
</tr>
<tr>
<td></td>
<td>tumors of the synovium</td>
</tr>
</tbody>
</table>
ANNEXURE II
CODASYL DATABASE DIAGRAM
SCHEMA MEDASEED
Annexure II
(contd)

CODASYL (SEED)
SCHEMA MEDASEED
DEFINED IN SEED
DATA DESCRIPTION
LANGUAGE
WITHIN LAMINATING
RECORD NAME IS POSSIBILITIES
LOCATION MODE IS CALC USING POSSIBILITIES=CONF
MUPITIERS ARE NOT ALLOWED
WITHIN LAMINATING
POSSIBILITIES=NAME TYPE IS CHARACTER
POSSIBILITIES=CONF TYPE IS INTEGER

SET NAME IS SET-PATIENT
NAME IS CHAIN LINKED TO PRINT
OWNER IS NEXT
OWNER IS NEXT
SET SELECTION IS THU
LOCATION MODE OF OWNER.

SET NAME IS CONSULTS
NAME IS CHAIN LINKED TO PRINT
OWNER IS NEXT
OWNER IS PATIENT
NAME IS NOT PATIENT
SET SELECTION IS THU
LOCATION MODE OF OWNER.

SET NAME IS PHARM-LICENS
NAME IS CHAIN LINKED TO PRINT
OWNER IS NEXT
OWNER IS PATIENT
OWNER IS TEST-PATIENT
SET SELECTION IS THU
LOCATION MODE OF OWNER.

SET NAME IS PHARM-ORDER
NAME IS CHAIN LINKED TO PRINT
OWNER IS NEXT
OWNER IS TEST
OWNER IS TEST-PATIENT
SET SELECTION IS THU
LOCATION MODE OF OWNER.

SET NAME IS PHARM-ORDER
NAME IS CHAIN LINKED TO PRINT
OWNER IS NEXT
OWNER IS NEXT
**Finite State Machine (FSM) Definitions**

- **Transition**
  - NEXT
- **Input**
  - TRUE
  - FALSE
- **Output**
  - TRUE
  - FALSE

**FSM Transition Details**

- **State A**
  - On input TRUE, transition to State B.
  - On input FALSE, remain in State A.

- **State B**
  - On input TRUE, transition to State C.
  - On input FALSE, remain in State B.

- **State C**
  - On input TRUE, transition to State A.
  - On input FALSE, remain in State C.
**** HENASEF IF SUMMARY STATISTICS, ****
2 ARFAS
IN RECORDS
24 ITEMS
7 SETS
**** THERE WERE 1 WARNINGS DETECTED, ****
**** THERE WERE 2 ERRORS DETECTED, ****
SUB-SHEMA FOR FORTRAN DATA MANIPULATION LANGUAGE
<table>
<thead>
<tr>
<th>Page</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$^o$C$^3$A</td>
</tr>
<tr>
<td>22</td>
<td>$^o$C$^3$A</td>
</tr>
<tr>
<td>21</td>
<td>$^o$C$^3$A</td>
</tr>
<tr>
<td>20</td>
<td>$^o$C$^3$A</td>
</tr>
<tr>
<td>20</td>
<td>$^o$C$^3$A</td>
</tr>
</tbody>
</table>
ANNEXURE III

DATABASE QUERIES USING THE HIGHER LEVEL PROCESSOR HARVEST

.RUN DDS: HARVEST

Welcome to 'D.11.10' HARVEST. Type HELP for info.

SUB-SCHEMA NAME: SUBMED
PASSWORD (<CR> IF NO PASSWORD): QUERY

COMMAND:

DISPLAY PATIENT-LAST-NAME PATIENT-CODE

PATIENT-LAST-NAME    PATIENT-CODE
JACKSON              101
GREEN                102
ROSY                 103
DREYFUS              104
SMITH                105

COMMAND:

DISPLAY DOCTOR-NAME DOCTOR-CODE

DOCTOR-NAME    DOCTOR-CODE
SMITH          11
JONES          12
WILLIAMS       14
ROCK           15

COMMAND:

WHERE PATIENT-LAST-NAME='JACKSON' DISPLAY TEST-NAME DATE-ORDERED

TEST-NAME       DATE-ORDERED
X-RAY           MAR 3, 82
IONE SCAN       MAR 11, 82
ARTHROSCOPY     MAR 11, 82

COMMAND:
ANNEXURE III (contd)

COMMAND:

WHERE PATIENT-LAST-NAME='GREEN' DISPLAY TEST-NAME DATE-ORDERED

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>DATE-ORDERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-RAY</td>
<td>FEB 16, 82</td>
</tr>
<tr>
<td>BONE SCAN</td>
<td>FEB 16, 82</td>
</tr>
<tr>
<td>SKIN CULTURE</td>
<td>FEB 16, 82</td>
</tr>
<tr>
<td>ARTHROSCOPY</td>
<td>3/10/82</td>
</tr>
<tr>
<td>ARTHROGRAM</td>
<td>3/10/82</td>
</tr>
<tr>
<td>ANA</td>
<td>3/10/82</td>
</tr>
</tbody>
</table>

COMMAND:

WHERE PATIENT-LAST-NAME='ROY' DISPLAY TEST-NAME DATE-ORDERED OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>DATE-ORDERED</th>
<th>OUTCOME-NAME</th>
<th>COST ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC</td>
<td>3/10/82</td>
<td>HG &lt; 8%</td>
<td>100</td>
</tr>
<tr>
<td>CBC</td>
<td>4/3/10/82</td>
<td>WBC INCREASED</td>
<td>100</td>
</tr>
<tr>
<td>CBC</td>
<td>3/10/82</td>
<td>LYMPHOCITES INCR</td>
<td>100</td>
</tr>
<tr>
<td>CBC</td>
<td>3/10/82</td>
<td>ESR &gt; 10 MH</td>
<td>100</td>
</tr>
<tr>
<td>X-RAY</td>
<td>3/10/82</td>
<td>LYTIC LESIONS/CYSTS</td>
<td>100</td>
</tr>
</tbody>
</table>

COMMAND:

WHERE PATIENT-LAST-NAME='ROY' TOTAL OF TEST-COST

TOTAL OF
TEST-COST

115.00

COMMAND:
ANNEXURE III (contd)

COMMAND:
WHERE DOCTOR-NAME='SMITH' DISPLAY PATIENT-LAST-NAME TEST-NAME VISIT-DATE

<table>
<thead>
<tr>
<th>PATIENT-LAST-NAME</th>
<th>TEST-NAME</th>
<th>VISIT-DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>JACKSON</td>
<td>X-RAY</td>
<td>MARCH 3, 82</td>
</tr>
<tr>
<td>JACKSON</td>
<td>BONE SCAN</td>
<td>MARCH 3, 82</td>
</tr>
<tr>
<td>JACKSON</td>
<td>ARTHROSCOPY</td>
<td>MARCH 3, 82</td>
</tr>
</tbody>
</table>

COMMAND:
WHERE DOCTOR-NAME='JONES' DISPLAY PATIENT-LAST-NAME VISIT-DATE TEST-NAME

<table>
<thead>
<tr>
<th>PATIENT-LAST-NAME</th>
<th>VISIT-DATE</th>
<th>TEST-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>X-RAY</td>
</tr>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>BONE SCAN</td>
</tr>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>SKIN CULTURE</td>
</tr>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>ARTHROSCOPY</td>
</tr>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>ARTHROGRAM</td>
</tr>
<tr>
<td>GREEN</td>
<td>FEB 16, 82</td>
<td>ANA</td>
</tr>
</tbody>
</table>

COMMAND:
WHERE TEST-NAME='X-RAY' DISPLAY TEST-OUTCOME-NAME

TEST-OUTCOME-NAME
NORMAL JOINTS
NORMAL BONE
JOINT EFFUSION
OSTEOPOROSIS
EROSIONS OF JOINT
LYTIC LESIONS/ CYSTS
ANKYLOSIS

COMMAND:
ANNEXURE III (contd)

COMAND:

WHERE TEST-OUTCOME-NAME='OSTEOPORESIS' DISPLAY POSSIBILITIES-NAME

POSSIBILITIES-NAME
HEMOPHILIA
JRA
PIGMENTED VILLONODULAR SYNOVITIS

COMAND:

WHERE POSSIBILITIES-NAME='JRA' DISPLAY TEST-NAME TEST-OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>TEST-OUTCOME-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONE SCAN</td>
<td>INCREASED UPTAKE</td>
</tr>
<tr>
<td>BLOOD CULTURE</td>
<td>WBC &lt; 2000</td>
</tr>
<tr>
<td>RECTAL CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>CBC</td>
<td>HEMOGLOBIN 8-11 G/M/L</td>
</tr>
<tr>
<td>ARTROGRAM</td>
<td>DYE-POPLITEAL CYST</td>
</tr>
<tr>
<td>ARTROGRAM</td>
<td>DYE-CALF AREA</td>
</tr>
<tr>
<td>ARTROGRAM</td>
<td>HYPERTROPIC SYNOVITUM</td>
</tr>
<tr>
<td>CBC</td>
<td>PLATELETS HIGH</td>
</tr>
<tr>
<td>ESR</td>
<td>ESR WINTROE &gt; 15MM</td>
</tr>
<tr>
<td>X-RAY</td>
<td>NORMAL BONE</td>
</tr>
<tr>
<td>ANA</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>X-RAY</td>
<td>JOINT EFFUSION</td>
</tr>
<tr>
<td>ARTROSCOPY</td>
<td>PANNUS FORMATION</td>
</tr>
<tr>
<td>ANA</td>
<td>POSITIVE</td>
</tr>
<tr>
<td>SKIN CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>THROAT CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>X-RAY</td>
<td>OSTEOPORESIS</td>
</tr>
<tr>
<td>ARTROSCOPY</td>
<td>CARTILEGE EROSION</td>
</tr>
<tr>
<td>X-RAY</td>
<td>EROSIONS OF JOINT</td>
</tr>
<tr>
<td>ARTROSCOPY</td>
<td>HYPERTROPIC SYNOVITUM</td>
</tr>
<tr>
<td>ARTROSCOPY</td>
<td>LOOSE BODY IN JOINT</td>
</tr>
<tr>
<td>X-RAY</td>
<td>ANKYLOSIS</td>
</tr>
</tbody>
</table>

COMAND:
ANNEXURE III (contd)

WHERE TEST-OUTCOME-NAME='OSTEOPOROSIS' DISPLAY POSSIBILITIES-NAME

POSSIBILITIES-NAME

HEMOPHILIA
JRA
PIGMENTED VILLONODULAR SYNOVITIS

WHERE POSSIBILITIES-NAME='JRA' DISPLAY TEST-NAME TEST-OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>TEST-OUTCOME-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONE SCAN</td>
<td>INCREASED UPTAKE</td>
</tr>
<tr>
<td>BLOOD CULTURE</td>
<td>WBC &lt; 2000</td>
</tr>
<tr>
<td>RECTAL CULTURE</td>
<td>NEGATIVE</td>
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<tr>
<td>CBC</td>
<td>HEMOGLOBIN 8-11 GM%</td>
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<tr>
<td>ARTHROGRAM</td>
<td>IYE-POPLITEAL CYST</td>
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<td>ARTHROGRAM</td>
<td>IYE-CALF AREA</td>
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<tr>
<td>ARTHROGRAM</td>
<td>HYPERTROPIC SYNOVUM</td>
</tr>
<tr>
<td>CBC</td>
<td>PLATELETS HIGH</td>
</tr>
<tr>
<td>ESR</td>
<td>ESR WINTROBE &gt; 15MM</td>
</tr>
<tr>
<td>X-RAY</td>
<td>NORMAL BONE</td>
</tr>
<tr>
<td>ANA</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>X-RAY</td>
<td>JOINT EFFUSION</td>
</tr>
<tr>
<td>ARTHROSCOPY</td>
<td>PANNUS FORMATION</td>
</tr>
<tr>
<td>ANA</td>
<td>POSITIVE</td>
</tr>
<tr>
<td>SKIN CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>THROAT CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>X-RAY</td>
<td>OSTEOPORESIS</td>
</tr>
<tr>
<td>ARTHROSCOPY</td>
<td>CARTILAGE EROSION</td>
</tr>
<tr>
<td>X-RAY</td>
<td>EROSIONS OF JOINT</td>
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<tr>
<td>ARTHROSCOPY</td>
<td>HYPERTROPIC SYNOVUM</td>
</tr>
<tr>
<td>X-RAY</td>
<td>LOOSE BODY IN JOINT</td>
</tr>
<tr>
<td>ANKYSLOSIS</td>
<td></td>
</tr>
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</table>
### ANNEXURE III (contd)

**Command:**

WHERE POSSIBILITIES-NAME='INFECTION ARTHRITIS' DISPLAY TEST-NAME TEST-OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>TEST-OUTCOME-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONE SCAN</td>
<td>INCREASED UPTAKE</td>
</tr>
<tr>
<td>BLOOD CULTURE</td>
<td>WBC &gt; 2000</td>
</tr>
<tr>
<td>RECTAL CULTURE</td>
<td>POSITIVE</td>
</tr>
<tr>
<td>BLOOD CULTURE</td>
<td>WBC &lt; 2000</td>
</tr>
<tr>
<td>RECTAL CULTURE</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>ARTHROGRAM</td>
<td>HYPERTROPIC SYNOVITM</td>
</tr>
<tr>
<td>CBC</td>
<td>WBC HIGHLY INCREASED</td>
</tr>
<tr>
<td>CBC</td>
<td>POLYMORPHS INCREASED</td>
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<tr>
<td>CBC</td>
<td>POLYMORPHS 1ND INCR</td>
</tr>
<tr>
<td>CBC</td>
<td>PLATELETS LOW</td>
</tr>
<tr>
<td>ESR</td>
<td>ESR WINTROBE &gt; 15MM</td>
</tr>
<tr>
<td>X-RAY</td>
<td>NORMAL JOINTS</td>
</tr>
<tr>
<td>ANA</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>SKIN CULTURE</td>
<td>POSITIVE</td>
</tr>
<tr>
<td>THROAT CULTURE</td>
<td>POSITIVE</td>
</tr>
<tr>
<td>X-RAY</td>
<td>JOINT EFFUSION</td>
</tr>
<tr>
<td>ARTHROSCOPY</td>
<td>PANNUS FORMATION</td>
</tr>
<tr>
<td>SKIN CULTURE</td>
<td>NEGATIVE</td>
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<tr>
<td>THROAT CULTURE</td>
<td>NEGATIVE</td>
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<tr>
<td>ARTHROSCOPY</td>
<td>CARTILAGE EROSION</td>
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<tr>
<td>X-RAY</td>
<td>EROSIONS OF JOINT</td>
</tr>
<tr>
<td>ARTHROSCOPY</td>
<td>HYPERTROPIC SYNOVITM</td>
</tr>
</tbody>
</table>

**Command:**

WHERE TEST-OUTCOME-NAME='ESR WINTROBE > 15MM' DISPLAY POSSIBILITIES-NAME

POSSIBILITIES-NAME

INFECTION ARTHRITIS

**Command:**
ANNEXURE III (contd)

REQUEST TEST-NAME='X-RAY' DISPLAY TEST-OUTCOME-NAME POSSIBILITIES-NAME

<table>
<thead>
<tr>
<th>TEST-OUTCOME-NAME</th>
<th>POSSIBILITIES-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORMAL JOINTS</td>
<td>INFECTIOUS ARTHRITIS</td>
</tr>
<tr>
<td>NORMAL BONE</td>
<td>JRA</td>
</tr>
<tr>
<td>JOINT EFFUSION</td>
<td>TRAUMATIC ARTHRITIS</td>
</tr>
<tr>
<td>JOINT EFFUSION</td>
<td>JRA</td>
</tr>
<tr>
<td>JOINT EFFUSION</td>
<td>INFECTIOUS ARTHRITIS</td>
</tr>
<tr>
<td>JOINT EFFUSION</td>
<td>BONE DISEASE WITH EFFUSION</td>
</tr>
<tr>
<td>JOINT EFFUSION</td>
<td>PIGMENTED VILLOUS SYNOVITIS</td>
</tr>
<tr>
<td>OSTEOPOROSIS</td>
<td>JRA</td>
</tr>
<tr>
<td>OSTEOPOROSIS</td>
<td>HEMOPHILIA</td>
</tr>
<tr>
<td>OSTEOPOROSIS</td>
<td>PIGMENTED VILLOUS SYNOVITIS</td>
</tr>
<tr>
<td>EROSIONS OF JOINT</td>
<td>JRA</td>
</tr>
<tr>
<td>EROSIONS OF JOINT</td>
<td>HEMOPHILIA</td>
</tr>
<tr>
<td>EROSIONS OF JOINT</td>
<td>INFECTIOUS ARTHRITIS</td>
</tr>
<tr>
<td>EROSIONS OF JOINT</td>
<td>ASEPTIC NECROSIS</td>
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<td>LYTIC LESIONS/ CYSTS</td>
<td>ASEPTIC NECROSIS</td>
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<td>BONE TUMORS</td>
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<tr>
<td>LYTIC LESIONS/ CYSTS</td>
<td>NEUROBLASTOMA</td>
</tr>
<tr>
<td>ANKYLOSIS</td>
<td>JRA</td>
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</table>

REQUEST POSSIBILITIES-NAME='NEUROBLASTOMA' DISPLAY TEST-NAME TEST-OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>TEST-OUTCOME-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC</td>
<td>HEMOGLOBIN &lt; 6g%</td>
</tr>
<tr>
<td>WBC</td>
<td>WBC HIGHLY INCREASED</td>
</tr>
<tr>
<td>PLT</td>
<td>PLATELETS LOW</td>
</tr>
<tr>
<td>EST</td>
<td>ESR WESTERGEN HIGH</td>
</tr>
<tr>
<td>X-RAY</td>
<td>LYTIC LESIONS/ CYSTS</td>
</tr>
</tbody>
</table>
ANNEXURE III (contd)

**COMMAND:**

WHERE POSSIBILITIES-NAME='LEUKEMIA' DISPLAY TEST-NAME TEST-OUTCOME-NAME

<table>
<thead>
<tr>
<th>TEST-NAME</th>
<th>TEST-OUTCOME-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBC</td>
<td>HEMOGLOBIN &lt; 6 GR</td>
</tr>
<tr>
<td>CBC</td>
<td>WBC HIGHLY INCREASED</td>
</tr>
<tr>
<td>CBC</td>
<td>LYMPHOCITES HIGH</td>
</tr>
<tr>
<td>CBC</td>
<td>PLATELETS LOW</td>
</tr>
<tr>
<td>ESR</td>
<td>ESR WESTERGEN HIGH</td>
</tr>
<tr>
<td>X-RAY</td>
<td>LYTIC LESIONS/ CYSTS</td>
</tr>
</tbody>
</table>

**COMMAND:**

WHERE TEST-NAME='ANA' DISPLAY TEST-OUTCOME-NAME POSSIBILITIES-NAME

YES? YOU HAVE INTERRUPTED ME.
TYPE C TO CONTINUE OR S TO STOP: C

**COMMAND:**

<table>
<thead>
<tr>
<th>TEST-OUTCOME-NAME</th>
<th>POSSIBILITIES-NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORMAL</td>
<td>NORMAL</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>TRAUMATIC ARTHRITIS</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>FOREIGN BODY ARTHRITIS</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>MECHANICAL DERANGEMENT</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>HEMOPHILIA</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>INFECTIOUS ARTHRITIS</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>JRA</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>BONE DISEASE CLOSE TO JOINT</td>
</tr>
<tr>
<td>NEGATIVE</td>
<td>SYNOVIAL SARCOMA</td>
</tr>
<tr>
<td>POSITIVE</td>
<td>JRA</td>
</tr>
</tbody>
</table>
COMMAND:

SHOW RECORDS

PATIENT
DOCTOR
DOCTOR-PATIENT
TEST-ORDERED
TEST
TEST-OUTCOME
TEST-LINE-ITEM
POSSIBILITIES

COMMAND:

SHOW SETS

DOCTOR-ORDERS
INDICATES
SEES-PATIENT
CONSULTS
HAS-ORDER
HAS-OUTCOME
INFERS
COMMAND:

SHOW ITEMS

RECORD: PATIENT
    PATIENT-LAST-NAME
    PATIENT-FIRST-NAME
    PATIENT-CODE
    PATIENT-AGE
    PATIENT-SEX
    PATIENT-ADDRESS
    PATIENT-FINAL-DIAGNOSIS

RECORD: DOCTOR
    DOCTOR-NAME
    DOCTOR-CODE
    DOCTOR-SCHEDULE
    DOCTOR-DEPT
    DOCTOR-SPECIALITY

RECORD: DOCTOR-PATIENT
    VISIT-DATE
    TRANSACTION-CODE

RECORD: TEST-ORDERED
    DATE-ORDERED
    OUTCOME-NAME
    OUTCOME-CODE

RECORD: TEST
    TEST-NAME
    TEST-CODE
    TEST-COST

RECORD: TEST-OUTCOME
    TEST-OUTCOME-NAME
    TEST-OUTCOME-CODE

RECORD: POSSIBILITIES
    POSSIBILITIES-NAME
    POSSIBILITIES-CODE

COMMAND:
COMMAND:

DISPLAY TEST-NAME

TEST-NAME

X-RAY
BONE SCAN
ARTHROSCOPY
ARTHROGRAM

ANP
BLOOD CULTURE
SKIN CULTURE
RECTAL CULTURE
THROAT CULTURE

CIC
CFT

COMMAND:

DISPLAY POSSIBILITIES-NAME

POSSIBILITIES-NAME

NORMAL
TRAUMATIC ARTHRITIS
FOREIGN BODY ARTHRITIS
MECHANICAL DERANGEMENT
HEMOPHILIA
INFECTION ARTHRITIS
JRA
OSTEOMYELITIS
BONE DISEASE WITH EFFUSION
BONE TUMORS
CHONDROMATOSIS
PIGMENTED VILLOUSULAR SYNOVITIS
SYNOVIAL SARCOMA
ASEPTIC NECROSIS
BONE DISEASE CLOSE TO JOINT
LEUKEMIA
NEUROBLASTOMA
BONE DISEASE
TRAUMA
CELLULITIS
DIMENSION KTEST(20)
COMMON /SORTWK/ KPOS(50,2), KHTTS, KSHORT(50,2), LENSH
CALL DADPEN ('SURFTN ', 'FORT ', 0)
C CHECK IF THERE IS AN ERROR WHEN OPENING THE DATABASE
IF (ERRSTA.EQ.0) GO TO 173
CALL ERROUT(S)
STOP
173 CONTINUE
DO 21 I=1,20
21 KTEST(I)=0
DO 23 I=1,50
   DO 25 J=1,2
      KSHORT(I,J)=0
      KPOS(I,J)=0
   25 CONTINUE
C BEGIN TRANSACTION WITH PATIENT CODE AS INPUT
C IT IS ASSUMED THAT EVERY PATIENT IS ASSIGNED A UNIQUE PATIENT
C CODE; THE PATIENT CODE IS THEREFORE CHOSEN TO BE THE CALC
C KEY FOR THE PATIENT RECORD IN THE DATABASE
C
C THE ARRAY KTEST STACKS THE TEST-OUTCOME CODES FROM THE DOCTOR-PATIENT
C RECORD. THE VARIABLE 'LIST' PERFORMS THE FUNCTION OF A STACK POINTER.
C INITIALISE LIST TO ZERO
LIST = 0
C EXTERNAL INPUT - PATIENT CODE FROM PERSON MAKING QUERY
WRITE (5,27)
27 FORMAT (/,'WHICH PATIENT DO YOU WISH TO DIAGNOSE ?',/,
      11X,'INPUT PATIENT CODE ?',/)
READ (5,*), PCODE
C LOOP 222 STACKS THE VARIOUS TEST OUTCOME CODES FOR THE PATIENT
C IN THE ARRAY KTEST; THE DEPTH OF THE STACK KTEST IS GIVEN BY THE
C INTEGER VARIABLE LIST
C
   CALL OBNTNC(PATENT,'FIRST')
   CALL ERRCHK
   WRITE (5,251) PLNAME, PCODE
   251 FORMAT ('PATIENT LAST NAME : ',3AS,1X,'PATIENT CODE : ',I6,/,)
C
C LOOP <222>
C
   DO 222 LCOUNT=1,100
      CALL FINDPO (LCOUNT, CONSRT)
C ERRSTA = 307 INDICATES END OF SET - THIS IS THE EXIT
C CONDITION FROM LOOP <222>
   IF (ERRSTA.EQ.307) GO TO 333
      CALL ERRCHK
C NESTED INNER LOOP <244> RETRIEVES THE TEST-OUTCOME RECORD
C FROM THE SET DOCTOR-ORDERS. ON ENCOUNTERING THE END OF SET, CONTROL IS
C TRANSFERRED TO THE MAIN LOOP WHICH FINDS THE NEXT DOCTOR-PATIENT RECORD
C
   DO 244 NCOUNT=1,100
      CALL OBTNPO (NCOUNT, DOCORD)
   IF (ERRSTA.EQ.307) GO TO 266
      CALL ERRCHK
   IF (OUTCDOE.EQ.0) GO TO 444
      LIST = LIST + 1
      KTEST(LIST) = OUTCDOE
C TRANSFER CONTROL TO LOOP ENTRY POINT
   GO TO 244
CONTD ... INTERN.FOR (page 2)

C OUTCOME CODE ≠ 0 IMPLIES THAT THE TEST RESULT IS AWAITED
C ENTER THIS PATH IF OUTCOME CODE ≠ 0
C PRINT OUT A REPORT INDICATING PATIENT NAME AND DETAILS OF THE TEST
C FOR WHICH THE RESULT IS AWAITED
C
C RETRIEVE THE TEST RECORD FROM THE DATABASE
C 440 CALL ORTNO (HSORDR)
C 244 CALL ERRCHK
C 263 WRITE ('5,263) TNAME, TORDR
C 263 FORMAT (1X,'TEST RESULT AWAITED FOR: ',TNAME,' TAKEN ON ',TORDR)
C RETURN CONTROL TO LOOP <244> ENTRY POINT
C 244 CONTINUE
C
C RESET ERRSTA TO ZERO
C 266 ERRSTA=0
C RETURN CONTROL TO MAIN LOOP <222> ENTRY POINT
C 222 CONTINUE
C
C EXIT FROM LOOP <222> WHEN END OF SET IS ENCOUNTERED
C
C
C RESET ERRSTA FROM 307 TO 0
C
C 333 ERRSTA=0
C
C THIS SECTION OF THE PROGRAM USES THE STACK KTEST OF DEPTH = LIST
C THE ELEMENTS OF THIS ARRAY ARE THE CALC KEYS OF THE TEST OUTCOME
C RECORDS USING THIS CALC KEY. THE DATABASE IS TRAVERSED TO PRODUCE
C A LIST OF DIAGNOSTIC POSSIBILITIES CORRESPONDING TO THE TEST
C OUTCOME CODE
C
C THE ARRAY KPOS HAS ITS FIRST COLUMN CONTAINING THE CALC KEY OF THE
C DIAGNOSTIC POSSIBILITY CODE AND THE SECOND COLUMN CONTAINING THE
C CALC KEY OF THE TEST OUTCOME CODE THAT WAS RETRIEVED USING THE PATIENT
C RECORD EARLIER. THE VARIABLE 'KHITS' PERFORMS THE FUNCTION OF A
C STACK POINTER
C
C LOOP <555> SCANS THE ELEMENTS OF THE STACK KTEST WHOSE DEPTH IS LIST
C
C STOP EXECUTION IF NO TEST RESULTS HAVE BEEN RECEIVED
C
C IF (LIST.EQ.0) STOP
C
C
C KHITS = 0
C DO 555 I=1, LIST
C ENSURE CURRENCY OF THE TEST-OUTCOME RECORD
C 555 TOUTCD = KTEST(I)
C CALL ORTMC (TOUTCD, 'FIRST')
C CALL ERRCHK
C RETRIEVE MEMBERS OF THE SET INDICT
C THIS IS THE TEST-LINE-IFLM INTERSECTION RECORD
C LOOP <561> SCANS THE MEMBER RECORDS IN THE SET INDICT
C THE EXIT CONDITION IS ERRSTA=307 INDICATING END OF SET
C THE VARIABLE HCOUNT IS THE LOOP COUNTER
C
C 561 DO HCOUNT=1, 100
C CALL FINDPO (HCOUNT, INDICT)
C EXIT CONDITION FOR LOOP <561>
C IF (ERRSTA.EQ.307) GO TO 567
C IF (ERRSTA.NE.0) CALL ERRCHK
C CALL ORTNO (INFER)
CALL ERRCHK
KHTS=KHTS + 1
KPOS(KHTS,1)=POSCOD
KPOS(KHTS,2)=TOUTCO
561 CONTINUE
C EXIT FORM LOOP <561> WHEN END OF SET IS ENCOUNTERED IN INDICT
567 ERRSTA = 0
C TERMINATION POINT OF LOOP <555>
555 CONTINUE
C
C SCAN THE ARRAY KPOS TO OBTAIN THE ARRAY KSHORT CONTAINING
C (DIAGNOSTIC POSSIBILITY, NUMBER OF OCCURANCES) PAIRS SORTED BY THE
C NUMBER OF OCCURANCES. THE VARIABLE 'LENSH' PERFORMS THE FUNCTION
C OF A STACK POINTER FOR KSHORT.
C
C INITIALISE LENSHT TO ZERO. THEN CALL THE SORT SUBROUTINE
LENSH = 0
CALL SORT
C
C THE PROGRAM Passes ON TO THIS STAGE AFTER STACKING THE ARRAY KPOS
C WITH ITS FIRST COLUMN HAVING THE POSSIBILITY CODE AND THE SECOND
C AND THE SECOND COLUMN HAVING THE TEST OUTCOME CODE
C KHTS IS THE 'DEPTH' OF THE KPOS ARRAY
C
C LOOP 888 SCANS THE FIRST COLUMN OF THE ARRAY KPOS FOR OCCURANCES OF
C THE SAME DIAGNOSTIC POSSIBILITY THAT OCCURS (IN SORTED ORDER).
C
C THIS LOOP PRINTS OUT THE DIAGNOSTIC POSSIBILITIES AS INDICATED
C BY THE VARIOUS TESTS RESULTS OF THE PATIENT IN QUESTION BY ACCESSING
C THE SEED DATABASE
C
WRITE (5,241)
241 FORMAT (5X,'CONSIDER THE FOLLOWING DIAGNOSTIC POSSIBILITIES:
1',/,'/',':',1,'/',':',1)
DO 868 I=1,LENSH
C PRINT OUT POSSIBILITY NAME, TEST NAME AND CORRESPONDING
C TEST OUTCOME NAME
PCOD = KSHORT(I,1)
CALL CRTNC(POSSIB,'FIRST')
CALL ERRCHK
WRITE (5,345) POSNAM
345 FORMAT (/,' ',/ 'POSNAM',/ ' ',/ 'LENSH')
C CHECK KSHORT(I,2) IF IT EQUALS 777. IF SO, PROCEED TO THE
C NEXT DIAGNOSTIC POSSIBILITY. THE SUBROUTINE ASSOC WOULD HAVE
C SET IT TO 777 IF IDENTICAL TEST OUTCOMES IMPLIED THE
C SAME DIAGNOSTIC POSSIBILITY.
C
IF (KSHORT(I,2).EQ.777) GO TO 888
C NOW SCAN REST OF ARRAY KPOS TO PRINT OUT POSSIBILITY NAMES
C AS INDICATED BY VARIOUS TESTS
WRITE (5,346)
346 FORMAT (41X,'INDICATED BY FOLLOWING',/,'134X',/,'RESULT',/,'J')
C
DO 899 J=1,KHTS
IF (KSHORT(I,1).NE.KPOS(J,1)) GO TO 899
TOUTCO=KPOS(J,2)
899 CONTINUE
KPOS(J,1)=999
CALL OBINC(TOUTCM,'FIRST')
CALL ERCKH
CALL ORTHO(HSOUTC)
CALL ERCKH
C PRINT OUT THE TEST OUTCOME CODE & TEST NAME
WRITE (5,347) TNAME,TOUTNM
FORMAT (/4,A25,2X,4A5)
347 CONTINUE
88A CONTINUE
   CALL ERCKH
   CALL DACLOS
END

C THE SUBROUTINE ERRCKH IS INVOKED AT EVERY POINT AFTER AN ATTEMPT
C TO ACCESS THE DATABASE IN MADE
C A SUCCESSFUL ACCESS RETAINS ERRSTA AS ZERO
C ANY ERROR IS REFLECTED IN THE ERRSTA CONDITION AFTER THE ACCESS
C ERRSTA = 307 INDICATES THAT THE END OF SET HAS BEEN ENCOUNTERED

C SUBROUTINE ERRCKH
INTEGER ERRSTA,DA
COMMON /DBASE/DB(63)
EQUIVALENCE (ERRSTA,DB(I))
IF (ERRSTA.EQ.0).OR.(ERRSTA.EQ.307) GO TO 357

C THE SEED SUBROUTINE ERRROUT DISPLAYS THE DETAILS OF THE ERROR
C CONDITION ON UNIT # 5
C THE PROGRAM IS TERMINATED IF THERE IS AN ERROR
   CALL ERRROUT(5)
   CALL DACLOS
   STOP
357 ERRSTA=0
RETURN
END

C SUBROUTINE SORT
COMMON /SORTWK/KPOS(50,2), KHITS, KSHORT(50,2), LENS
COMMON /ASSCWK/KASHW(50), KASPTR
DIMENSION KWORK(50)
KASPTR = 0
DO 472 I=1,50
472 KWORK(I) = KPOS(I,1)
LENS = 0
DO 355 I = 1,KHITS
   NHITS = 1
   KASPTR = KASPTR + 1
   KASSWK(KASPTR) = KPOS(I,2)
   IF (KWORK(I).EQ.999) GO TO 355
   IF (I.EQ.KHITS) GO TO 474
   DO 357 J = I+1, KHITS
      IF (KWORK(I) .NE. KWORK(J)) GO TO 357
      NHITS = NHITS + 1
      KASPTR = KASPTR + 1
      KASSWK(KASPTR) = KPOS(J,2)
      KWORK(J) = 999
357 CONTINUE
474 LENS = LENS + 1
   KSHORT(LENS+1) = KWORK(I)
KSHORT(LENSH,2) = NHITS
355 CONTINUE
   IF (LENSH .EQ. 1) GO TO 479

C
C BUBBLE SORT ARRAY KSHORT BY COLUMN 2
C COLUMN 2 CONTAINS THE COUNTER NHITS INDICATION THE
C NUMBER OF TIMES THE POSSIBILITY WAS INDICATED
C
DO 365 I = 1, LENSH-1
   DO 367 J = I+1, LENSH
      IF (KSHORT(I,2) .GE. KSHORT(J,2)) GO TO 367

C BEGIN SWAP
   KTEMP1 = KSHORT(I,1)
   KTEMP2 = KSHORT(I,2)
   KSHORT(I,1) = KSHORT(J,1)
   KSHORT(I,2) = KTEMP1
   KSHORT(J,1) = KTEMP2
C END SWAP
367 CONTINUE
365 CONTINUE
C CALL SUBROUTINE ASSOC - WHICH CHECKS THE STACK KSHORT FOR DIFFERENT
C POSSIBILITIES INDICATED BY IDENTICALLY SAME TEST OUTCOMES
C
CALL ASSOC
479 RETURN
END

C
SUBROUTINE ASSOC
COMMON / SORTHK/ KPOS(50,2), KSHORT(50,2), LENSH
COMMON / ASSCHK/ KASSWK(50), KASPTR
LOGICAL SAME
KINIT = 1,
   IF (LENSH .EQ. 1) RETURN
DO 367 I = 1, LENSH-1
   CALL BUBBLE (KINIT,KSHORT(I,2))
   KINIT = KINIT + KSHORT(I,2)
367 CONTINUE
   KINIT = 0
   DO 383 I=1, LENSH-1
      KINIT = KINIT + KSHORT(I,2)
      IF (KSHORT(I,2) .NE. KSHORT(I+1,2)) GO TO 383
      CALL COMPAR (KINIT,KSHORT(I,2),SAME)
     IF (NOT SAME) GO TO 383
C SET KSHORT(I,2) TO 777 IF THE DIAGNOSTIC POSSIBILITY
C KSHORT (I,1) IS INDICATED BY THE SAME TEST OUTCOMES AS THAT
C IN KSHORT (I+1,1)
   KSHORT(I+1,2) = 777
383 CONTINUE
RETURN
END

C
SUBROUTINE BUBBLE (KSTART,KLEN)
COMMON / ASSCHK/ KASSWK(50), KASPTR
C
C THE SUBROUTINE BUBBLE SORTS THE INTEGERS STORED IN KASSWK(50)
C STARTING FROM POSITION 'KSTART' UPTO KSTART + KLEN.
C
   IF (KLEN .EQ. 1) RETURN
   DO 376 J = KSTART, KLEN-1
   DO 378 K = J+1, KLEN
      IF (KASSWK(J) .LT. KASSWK(K))
         CALL SWAP (KASSWK(J),KASSWK(K))
      END IF
376 CONTINUE
378 CONTINUE
IF (KASSWK(J) .GE. KASSWK(K)) GO TO 378

C ELSE BEGIN SWAP

  KTEMP4 = KASSWK(J)
  KASSWK(J) = KASSWK(K)
  KASSWK(K) = KTEMP4

C END SWAP

378 CONTINUE

376 CONTINUE

RETURN

END

SUBROUTINE COMPAR (KNEXT, KLEN, SAME)
COMMON / ASSCHK/, KASSWK(50), KASPTR

C THIS SUBROUTINE COMPARES THE SORTED CALCE KEYS OF THE TEXT OUTCOME CODES
C INDICATING THE SAME DIAGNOSTIC POSSIBILITY AND SETS THE LOGICAL
C VARIABLE 'SAME' TO 'TRUE' IF THEY ARE IDENTICAL.

C

LOGICAL SAME
SAME = .FALSE.
DO 381 I = 1, KLEN
  KFIRST = KNEXT - KLEN
  IF (KASSWK(KFIRST + I) .NE. KASSWK(KNEXT + I)) GO TO 382
  CONTINUE
SAME = .TRUE.
381 CONTINUE
382 RETURN

END
WHICH PATIENT DO YOU WISH TO DIAGNOSE?
INPUT PATIENT-CODE:

101

PATIENT LAST NAME: JACKSON  PATIENT CODE: 101

CONSIDER THE FOLLOWING DIAGNOSTIC POSSIBILITIES:

HEMOPHILIA
INFECTIONOUS ARTHRITIS
JRA

INDICATED BY FOLLOWING
TEST  RESULT

ARTHROSCOPY  PANNSUS FORMATION
BONE SCAN  INCREASED UPTAKE
X-RAY  EROSIONS OF JOINT

ASEPTIC NECROSIS

INDICATED BY FOLLOWING
TEST  RESULT

BONE SCAN  INCREASED UPTAKE
X-RAY  EROSIONS OF JOINT

BONE TUMORS

INDICATED BY FOLLOWING
TEST  RESULT

BONE SCAN  INCREASED UPTAKE

END OF EXECUTION
CPU TIME: 0.68  ELAPSED TIME: 50.52
EXIT
EXECUTE INTERN, DGSI: DML/SEA
LINK: Loading
[LNX:CT INTERN Execution]

WHICH PATIENT DO YOU WISH TO DIAGNOSE?
INPUT PATIENT-CODE:

103

PATIENT LAST NAME: ROY              PATIENT CODE: 103

CONSIDER THE FOLLOWING DIAGNOSTIC POSSIBILITIES:

**LEUKEMIA**

<table>
<thead>
<tr>
<th>TEST</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-RAY</td>
<td>LYTIC LESIONS/ CYSTS</td>
</tr>
<tr>
<td>ESR</td>
<td>ESR WESTERGEN HIGH</td>
</tr>
<tr>
<td>CBC</td>
<td>LYMPHOCITES HIGH</td>
</tr>
<tr>
<td>CBC</td>
<td>WBC HIGHLY INCREASED</td>
</tr>
<tr>
<td>CBC</td>
<td>HEMOGLOBIN &lt;8 GM/L</td>
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**NEUROBLASTOMA**

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**BONE TUMORS**

**ASEPTIC NECROSIS**

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**INFECTIOUS ARTHRITIS**

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<tbody>
<tr>
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<td>WBC HIGHLY INCREASED</td>
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</table>

END OF EXECUTION

CPU TIME: 0.89  ELAPSED TIME: 1:10.23
EXIT