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An official publication of the Computer Society of South Africa and of the South African Institute of Computer Scientists

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QUESTIONES INFORMATICÆ

An official publication of the Computer Society of South Africa and of the South African Institute of Computer Scientists

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Questiones Informaticæ is prepared by the Computer Science Department of the University of the Witwatersrand and printed by Printed Matter, for the Computer Society of South Africa and the South African Institute of Computer Scientists.
A high-level language for accessing a relational database is being developed at UCT. The system, known as HAL (High-level Access Language), provides complete data independence as users view the database in terms of objects and their properties. Constraints on data usage can be incorporated in the data definition and enforced by HAL. In this way a simpler, more controlled interface to a relational database is obtained.

KEY WORDS: relational database, access language, metadata, data independence, subschema

1. INTRODUCTION

Relational databases are easier to use than others primarily because their non-procedurality reduces the navigation problems of the earlier systems. However they still require a thorough knowledge of the relational structure of the data and the correct use of non-trivial operations such as join, which is a form of navigation in that it enables one to pass from one relation to another. The HAL project was initiated to present the programmer with a natural view of data as objects and their properties, where no knowledge of the underlying relations is required. Additional advantages of HAL are enforcing more integrity constraints on data and enabling the metadata (data definition) to be accessed as well as data.

This paper describes the HAL subschema and data manipulation language. Implementation considerations are then outlined and the system evaluated by comparison with conventional relational languages.

2. THE HAL SUBSCHEMA

An example of a simple subschema can be seen in the appendix. A HAL subschema comprises a list of objects optionally followed by a list of tasks. An object is described by several properties each associated with an attribute or relation in the database. The tasks are database manipulating routines which can be called from within programs. Every property is designated as mapping to 1 or M (many) values and has a valuetype which is STRING, INTEGER, REAL, or an object name. The latter case implies that the property references other objects in the database. The application programmer sees only a list of object and property names, and a list of task names.

Constraints can stipulate that certain properties are "compulsory" and cannot be null, or are "id-properties" and cannot have duplicate values. Further, where ever a property of one object references another object (called a "foreign key"), the update and deletion of the foreign object can be specified as nullifying or cascading through to the property, or as being restricted by the property.

"Tasks" [8] are useful for standard operations: it is preferable to store the handling of data once with the data definition, than many times over in programs that use it, possibly inconsistently. A task can have parameters and local variables and can return a result. Tests can be interspersed with executable statements to verify conditions at that particular point. An exception-handling task specified with a test will be invoked whenever the test fails.

3. THE DATA MANIPULATION LANGUAGE

The HAL commands are GET, CREATE, DELETE, UPDATE and NULLIFY. The latter is
a special form of UPDATE which allows individual values of a multivalued property to be nullified, leaving other values of that property intact. The user requires no knowledge whatsoever of how the data is stored; he need only know what properties of objects exist. Commands reference data by property names and deal with sets of objects rather than working on an object-by-object basis. So that programmers need not know the ordering of properties within an object, the property, not the object, is the unit of access. Any combination of properties in any order can be referred to in one statement, and GET can retrieve properties of different kinds of object at the same time. Particular object occurrences to be affected by a command are selected by a predicate expressed in terms of any properties of the object, not only its "key" properties.

The option of file output is provided for extracting large numbers of objects from the database. Arithmetic operations and aggregate functions (average, minimum, maximum, sum, and count) can be applied to database values, and any desired sequencing of objects in a result can be obtained. The concise notation enables multivalued and compound properties, and properties of properties to be referenced easily. Consider the following statement for the HAL subschema in the appendix:

CREATE project(name="IBM"; jobhistory.worker.name, jobhistory.hours="Doe", 36, "Tod", 45, "Fig", 27)

Jobhistory is a compound, multivalued property of project which is here being given three values. Each of these comprises a pair of worker-name and hours values, respectively. A "mapping" [6] permits properties of properties to be designated simply: example "jobhistory.worker.name". Special forms of GET are provided to enable metadata to be retrieved. Examples:

GET(obj = OBJECT, del = DELETES, edit = UPDATES) ;
retrieves all object names with their deletion and update constraints;

GET(prop=PROPERTY, of=OBJECTOF, t=TYPE, c=COMPULSORY, u=UNIQUE, m=MULTIPLICITY);

obtains all property names and descriptions.

The commands are designed to be embedded within a C [7] host language program so their syntax is compatible with that of C. The major difference lies in the fact that C is record-oriented while HAL is set-oriented. This problem is overcome by treating a retrieval statement as a loop control. The (compound) statement following a GET is iterated once for every object retrieved. HAL commands could not be implemented as library routines because of problems with parameter passing for complex predicates. Instead, a preprocessor replaces HAL statements within a C program by appropriate commands manipulating the underlying database. It should be noted that the overhead of such a preprocessor pass through a program exists in most relational database systems.

4. IMPLEMENTATION

The metadata in the HAL subschema is stored in the following relations in the database:

- **RELATIONS** - this stores the relation and attributes in the underlying database as well as their data type
- **OBJECTS** - here there are tuples for each object type and every relation in which that object is referenced. If the object is a foreign key the restrict/cascade/nullify information is recorded along with the name of the foreign key attribute
- **PROPERTIES** - this gives the attribute or relation representing each property. If a relation, the property is termed "complex" (eg. jobhistory and workdone in the appendix.) The objecttype and id columns in PROPERTIES indicate foreign keys. In the appendix "worker" and "operation" are two such properties mapped to work.eno (specifying workers via their employee number) and work.jno
JOINS -

this gives the attributes to match when joining one relation to another for a complex property.

The appendix illustrates the metadata created for a simple subschema.

The HAL preprocessor parses commands, checks them against the stored metadata and translates them into equivalent operations on the relational database. When a task is invoked the preprocessor extracts any condition associated with the call in the program, translates it into an equivalent predicate on the underlying database and appends it to all database manipulation commands in the task. The system is being tested on an Ingres database and hence HAL statements are translated to EQUEL [9]. A HAL command generally requires several EQUEL operations, since what appears to the programmer as a single object is usually represented by several relations. The preprocessor deduces that a join is required when it encounters a foreign or complex property.

Consider firstly the handling of a foreign key such as worker. Its PROPERTIES entry equates it with work.eno, and its "objecttype" and "id" indicate that it references employee objects by number. Employee number is found in PROPERTIES to be represented by emp.eno. Thus the join clause "WHERE work.eno = emp.eno" is used. For a complex property, PROPERTIES shows that it is represented by an entire relation. The JOINS tuple for that property is thus examined to obtain the join clause.

Handling CREATE, NULLIFY and UPDATE commands requires that properties be re-ordered before equivalent EQUEL statements are devised. In this way properties in one relation are treated, then those in the next relation, and so on. When the PROPERTIES entry indicates that a complex property is being inserted, the metadata for the corresponding relation is examined to determine its compulsory properties. Unfortunately, the foreign key value may be given under some other property name, eg:

```
CREATE project(number=102; name="NCR"; jobhistory.hours, jobhistory.worker.name=12, "Doe", 24, "Fig", 9 "Poe");
```

The HAL system has to impose all subschema constraints. To enforce restricted updates and deletions, a RETRIEVE ANY is used to detect tuples preventing the desired operation. Additional EQUEL statements are created to propagate changes and deletions through the database. Finally, enforcing uniqueness of id-properties involves using ANY to detect duplicates.

```
CREATE activity(worker.name, hours, operation.number="Doe", 12, 24, "fig", 27, 18, "Poe", 33, 3);
```
5. EVALUATION

The major advantages of HAL over existing relational languages are that several underlying relations can be referenced in one statement as if the information were all stored together, and that objects can be uniquely distinguished via any identifier. There is no need to distinguish "attributes" from "associations" even though they may be implemented differently and the join operation of their relational algebra is replaced by the simple concept of a mapping. In addition HAL can restrict data removal and alteration where appropriate, detect duplicates or null values where they are not allowed, and propagate deletions and updates through the database. The metadata relations created by the system are accessible to programmers, enabling them to query the data definition. Figure 1 illustrates the relative simplicity of HAL compared with the conventional database languages: relational algebra[5], relational calculus[4], EQUEL[9] and SQL[1]. Query: Give the names of all employees who have worked on the "ICL" project (for the database in the appendix).

Phrasing the same query in HAL:

```
GET (result=jobhistory.worker.name) WHERE project.name == "ICL";
```

Phrasing the sample query in the relational algebra:

```
JOIN emp AND work OVER eno GIVING temp1
JOIN temp1 AND job OVER jno GIVING temp2
SELECT temp2 WHERE jname = "ICL" GIVING temp3
PROJECT temp3 OVER ename GIVING result
```

Phrasing the sample query in the relational calculus:

```
RANGE wx work
RANGE jx job
GET result(emp.ename): \exists wx \exists jx(emp.eno = wx.eno & wx.jno = jx.jno & jx.jname = "ICL")
```

Phrasing the sample query in EQUEL:

```
RANGE OF ex IS emp
RANGE OF jx IS job
RANGE OF wx IS work
RETRIEVE (result=ex.ename) WHERE ex.eno=wx.eno and wx.jno=jx.jno and jx.jname = "ICL"
```

Phrasing the sample query in SQL:

```
SELECT ename
FROM emp
WHERE eno IN (SELECT eno
  FROM work
WHERE jno IN (SELECT jno
    FROM job
WHERE jname = "ICL"))
```

**figure 1**

Comparison of Five Relational Languages

HAL has demonstrated that a high-level interface to a relational database can provide complete data independence, thus enhancing ease of use and making programs immune to changes in the schema. The major problem remaining is that the data manipulation commands are embedded in a foreign host programming language. A persistent programming language based on HAL is accordingly being developed[2].
REFERENCES

9. NCR Corp. [1983], *TOWER Database Manager*, Relational Technology Inc.

APPENDIX - SIMPLE EXAMPLE

Employee-Work Database Relations

```plaintext
EMP(ename, eno, wage)
JOB(jname, jno, charge)
WORK(jno, eno, hrs)
```

Subschema for Employee-Work Database (The TRANSLATION section is transparent to application programmers)

```plaintext
OBJECT Employee
   ID-PROPERTY
   Name
   Number
   PROPERTIES
   Wage
   Workdone

OBJECT Project
   ID-PROPERTY
   Name
   Number
   PROPERTIES
   Charge
   Jobhistory

OBJECT Activity
   ID-PROPERTY
   Operation
   Worker
   PROPERTIES
   Hours

TRANSLATION
OBJECT Employee
   Name
   Number
   Wage
   Workdone

OBJECT Project
   Name
   Number
   Charge
   Jobhistory

EMP.ename
EMP.eno
EMP.wage
WORK
JOB.jname
JOB.jno
JOB.charge
WORK
```
OBJECT Activity
Operation WORK.jno = Project.Number
Worker WORK.eno = Employee.Number
Hours WORK.hrs

Metadata for above subschema

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(in the above relation the names "compulsory", "multiplicity" and "unique" have been abbreviated to "c", "m" and "u" respectively).

JOINS

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<td>emp</td>
<td>eno</td>
<td>work</td>
<td>eno</td>
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