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Expressions as Data in Relational Data Base Management Systems

Maresh Saravanan
University of New Orleans

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Expressions as Data in Relational Data Base Management Systems

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
In
The Department of Computer Science

By

Mahesh Saravanan

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ABSTRACT

Numerous applications, such as publish/subscribe, website personalization, applications involving continuous queries, etc., require that user's interest be persistently maintained and matched with the expected data. Conditional Expressions can be used to maintain user interests. This thesis focuses on the support for expression data type in relational database system, allowing storing of conditional expressions as 'data' in columns of database tables and evaluating those expressions using an *EVALUATE* operator. With this context, expressions can be interpreted as descriptions, queries, and filters, and this significantly broadens the use of a relational database system to support new types of applications. The thesis presents an overview of the expression data type, storing the expressions, evaluating the stored expressions and shows how these applications can be easily supported with improved functionality. A sample application is also explained in order to show the importance of expressions in application context, with a comparison of the application with and without expressions.

1. INTRODUCTION

A wide-range of applications, including Publish/Subscribe [8], Workflow, and Website Personalization [5], require maintaining user's interest in expected data as conditional expressions. The following example [8] shows a simple publish/subscribe application that requires maintaining user's interest in expected data.

Example:

Let us consider a transport system where an operator has many things going on at once.

- *There may be buses following different routes with passengers who want to know the status of their bus and when it will arrive at their stop.*
- *There may also be operators who need to know the status of the bus fleet from time to time.*
- *More specifically the passengers would probably be interested in the current status of their bus, when it will arrive at their stop, and what buses do and will stop at their station. Most of what they will be interested in will be short-lived information. That is information that is transient and has little or no value to them once the moment has passed, since there will be more up-to-date information available or about to become available.*

The operators, on the other hand, would possibly be interested in where all the buses are at a given time, whether they are on schedule or experiencing any delays, which buses have problems, and whether there are any breakdowns within the fleet. Some of this information is transient, but if it is retained it provides an historical picture of events that may be useful input to other processes.

The transport provider would like to have all the information available to the different consumers via Web pages where they can select what information they need. In another context, the users could register their email addresses in web pages and select the information they need at the time of registration. User's email addresses and the user's interests can be stored in terms of conditional expressions. The information will arrive periodically in their inbox.

As the buses travel around their routes they need to log their position each time they stop, get delayed, or breaks down. This information can then be made available to all consumers on demand, or for subscribed users as alerts on delays, late schedules, etc.

Applications requiring continuous queries provide another motivation for use of conditional expressions. According to [3], continuous queries [4] [9] [10] [11] allow users to obtain new results from a database without having to issue the same query repeatedly. Continuous queries are especially useful in an environment like the Internet that comprises of large amounts of frequently changing information. A set of continuous queries can be modeled as a collection of expressions that can be stored for later querying usage. This is done to avoid redundant retrieval of results by consolidating a large set of queries to a smaller set of common expressions thereby saving a lot of time in data retrieval.

The following is an example of how and why we use expressions.

Example:

Let us consider a Car Buy/Sell business. There may be many forms of user's interests, some of these modeling interests of sellers and others modeling interests of buyers. Some of them may be

- *A buyer may be interested in one or more cars that match specific criteria, such as price, model, etc.*
- *A car may be of interest to one or more buyers with matching criteria.*
- *A seller may be interested in buyers in particular income brackets.*

To match incoming data about cars to relevant buyers, and to match new buyers and sellers to each other, user interest may be modeled as conditional expressions that allow later manipulations and easier information retrieval.

The information that are hence retrieved, may answer one of the following questions.

- *What cars are of interest to each consumer?*
- *What sort of buyers are of interest to each seller?*
- *What kind of demand exists for each car? This can help to determine optimal pricing.*
- *Is there any unsatisfied demand? This can help to determine inventory requirements.*

This thesis proposes to manage such expressions as data in Relational Database Systems (*RDBMS*). This is accomplished 1) by allowing expressions to be stored in a column of a database table and 2) by introducing a *SQL EVALUATE* operator to evaluate expressions for given data. Expressions when combined with predicates on other forms of data in a database are a flexible and powerful way of expressing interest in a data item. The ability to evaluate expressions (via *EVALUATE* operator) in *SQL*, enables applications to take advantage of the expressive power of *SQL* to support complex subscription models.

The terminology used in this thesis is explained in the rest of this chapter. In chapter 2 this thesis explains the related work and points out the difference between the related work and

the approach taken in this thesis. Chapter 3 describes the expression datatype used in this thesis. In the following chapter implementation of the expression datatype in a simulated mini Data Base Management Systems (DBMS) is explained. Chapter 5 explains a sample application and describes the data management aspect of the application both with and without the use of expression data type. Chapter 6 outlines future enhancements and chapter 7 concludes the thesis.

1.1 TERMINOLOGY USED:

EXPRESSION:

An expression is a combination of identifiers, values, and operators that can be evaluated to obtain a result. Expressions can be used, for example, as a search condition when looking for data that meets a set of criteria. Expressions are a useful way to describe interests in expected data.

Expressions are nothing but conditions. They evaluate to true or false depending on the incoming data and the user's interest.

Example:

Let us consider a table, Car, which has details about various cars such as model, price year, color, mileage etc. A select statement against the table to select all cars less than 20000 dollars and manufactured in or after 2000 can be represented as follows.

*Select * from Cars where Car.Price < 20000 and Car.Year >= 2000*

Here, "Car.Price < 20000 and Car.Year >= 2000" is the expression.

PREDICATE:

Subparts of an expression are called predicates. A valid expression consists of one or more simple conditions called predicates. The predicates in the expression are linked by the logical operators AND and OR. In this thesis, however, only the AND operator is supported.

Example:

Let us consider the same example as in expression of a table, Car, and let us consider the same expression. “Car.Price < 20000 and Car.Year >= 2000”. Here the predicates are

Predicate 1 - “Car.Price < 20000”

Predicate 2 - “Car.Year >= 2000”

Combining Predicates on other forms of data, like functions, in a database is just a powerful way of expressing interest.

EVALUATE

The EVALUATE operator is used to compare stored expressions to incoming data items. The EVALUATE operator returns a 1 for an expression that matches the data item, and returns a 0 for an expression that does not match the data item. For a given input data item, EVALUATE operator checks if any Expressions evaluates to True. EVALUATE operator returns 1 if an Expression is evaluated to True for a given input data-item. It will be discussed further in the coming sections of this document.

DATA ITEM:

As described above, expressions model the condition part of queries in relational databases. Expressions are evaluated against data items. For expressions, data items can thus be

considered analogous to tables against which queries are evaluated. An Expression evaluates to *True* if the incoming data-item meets the user's interest, and if the incoming data-item does not meet the user's interest then the Expression evaluates to *False*.

DATA ITEM CONSTITUENT:

The data item constituents are the sub parts of a data item. The relationship of data item constituents to a data item is similar to the relationship of predicates to an expression.

Example:

Let us consider a data item for the expression example that is given under 'expression'. A data item may be of the form

"Car.Price = 15000 and Car.Mileage = 25000

The data item constituents for the above mentioned data item are

Data item constituent 1: Car.Price = 15000

Data item constituent 2: Car.Mileage = 25000

2. RELATED WORK

Major software vendors, such as Oracle, IBM, Microsoft, provide support for conditional expressions. The approach taken by Oracle, described in [1], is most relevant to this thesis and is discussed next. A description of the functionality provided by IBM and Microsoft is given later in this chapter. The chapter concludes with a discussion, highlighting the differences in the approach used in this thesis and the existing approaches.

2.1 EXPRESSION FILTER IN ORACLE 10 G

Conditional expressions can be used to describe interest in information. One could consider expressions in isolation, as publish/subscribe systems generally do, or as part of a more general description of message consumers. Expression Filter is a feature of the Oracle Database 10g that allows application developers to store, index, and evaluate conditional expressions in one or more columns of a relational table. Expressions are a useful way to describe interest in some expected data. Applications involving information distribution, demand analysis, and task assignment can benefit from Expression Filter.

Oracle 10G Expression Filter matches expressions in a column with a data item passed by a SQL statement or with data stored in one or more tables, and evaluates each expression to be true or false.

Example:

Consider an application that matches buyers and sellers of cars. A table called Consumer describes the buyers. This table consists of multiple columns, such as Name, Identification, address of consumer, and their interest in a column called INTERESTS that has an Expression datatype. The INTERESTS column stores an expression for each consumer that

describes the kind of car the consumer wants to purchase, including make, model, year, mileage, color, options, and price. A sample table is shown below.

Name	ID	Address	Interests
John	U2001	1, A	Car.Model = Taurus and Car.Year = 2000
Ben	U2003	2, B	Car.Model = Toyota and Car.Price < 20000
Anna	U2004	3, C	Car.Model = Taurus and Car.Year > 2002

Table 1 Consumer Table

Expression Filter can match incoming data with conditional expressions stored in the database to identify rows of interest. Specifically, a new SQL EVALUATE operator is provided that matches the incoming data items with the expressions to find prospective buyers.

*SELECT * FROM Consumers WHERE*

EVALUATE (Consumer.Interest) ..., <DATA ITEM>) = 1

This statement returns those rows for which the expressions match the values of the data item. Data about cars for sale is included with the EVALUATE operator in the SQL WHERE clause.

The previous example showed how incoming data is filtered based on subscriber interest. With the addition of the expression data type in the relational database management system, it also becomes easy for a publisher to filter recipients of information as the following examples shows.

A publisher could issue a query to find rows that satisfy certain criteria, for example, find every Customer who is located in a particular locality. The result set could be used to define the consumers of particular data item. In this case the publisher determines the recipients with a SELECT on the table.

The SQL EVALUATE operator also enables batch processing of incoming data.

Data can be stored in a table called CARS and matched with expressions stored in the CONSUMER table using a join between the two tables.

2.1.1 Elements

Expression Filter includes the following elements

- Expression datatype - a virtual datatype created through a constraint placed on a *VARCHAR* column in a user table that stores expressions
- *EVALUATE* operator - an operator that evaluates expressions for each data item
- Administrative utilities - set of utilities that validate expressions and suggest optimal index structure
- Expression indexing - enhances performance of the *EVALUATE* operator for large expression sets. Expression indexing is available in Oracle Database Enterprise Edition

2.1.2 Expression Filter Usage Scenarios

1. To screen incoming data

- Find matches with expressed interests or conditions
 - We have found an item that may be exactly what you're looking for (based on your personal preferences)
 - A suspect has just entered the country (given the terrorist screening guidelines provided by the authorities)
- Find non-matches
 - This new piece of data does not meet one of (y)our standards
 - This record does not adhere to this business rule

2. To screen existing data for new interests, conditions, standards or rules
 - Because of this new EU regulation, we have to redesign these products
3. To dynamically bundle up multiple queries

2.1.3 Application Characteristics

Expression Filter is a good fit for applications where the data has the following characteristics:

- A large number of data items exists to be evaluated
- Each data item has structured data attributes, for example *VARCHAR*, *NUMBER*, *DATE*, *XMLTYPE*
- Incoming data is evaluated by a significant number of unique and persistent queries containing expressions
- The expression (in *SQL WHERE* clause format) describes an interest in incoming data items
- The expressions compare attributes to values using relational operators (=, !=, <, >, and so on)

2.1.4 Sample Queries

Let us consider a situation where a user (in this case a car dealer) is interested in all consumers interested in a Mustang car which was made in the year 2000 and which costs 18000 dollars and has run 22000 miles. Assume that the consumer information is stored in the Consumer table introduced in Section 2.1 where the Interest column stores their interests in the form of

expressions. A query to cater such a dealer's need in terms of Oracle's expression filter would be as follows:

```
SELECT * FROM Consumer WHERE
```

```
EVALUATE (Consumer.Interest, 'Model=>'Mustang'', Year=>2000, Price=>18000,
```

```
Mileage=>22000') = 1;
```

2.1.5 Support by other vendors

Apart from Oracle, other vendors such as IBM, Microsoft etc have also contributed to support this functionality. For example **IBM** developed GRYPHON, IBM: Gryphon [13] AND Microsoft developed SCRIBE [2].

Gryphon was designed and implemented to provide content-based publish/subscribe functionality using the fast, scalable routing algorithms. Clients access the system through implementation of the Java Message Service (JMS) API.

Microsoft also supported a similar thing in SQL Server called **SCRIBE (Notification Services)**. Scribe is a **topic-based system**. Scribe is the premier platform for developing and deploying highly scalable notification applications. Capitalizing on the Microsoft .NET Framework and SQL Server, Notification Services provides an easy-to-use programming model for generating and formatting notifications based on personal subscriptions. This device-independent architecture can accept event data from any source and securely deliver it to a variety of mobile devices, including personal digital assistants (PDAs), cellular telephones, and more.

Even though other vendors have support for publish/subscribe technology through specific systems such as Gryphon and Scribe, the main difference between Oracle expression data type is that, in Oracle, the functionality is built and implemented within the database. In other words, the expressions are stored in a column of a table so that no extra resource / utility needs to be installed separately.

Another advantage by using Oracle's approach for publish/subscribe is that, by using Oracle's approach, both publish and subscribe can be implemented with the same methodology, which means, it doesn't have to be two different implementation approaches, one for publish and the other for subscription.

One other important feature of the Oracle's expression data type is the EVALUATE operator which is not present in both Gryphon and the Scribe. The SQL EVALUATE operator saves time by matching a set of expressions with incoming data. This saves labor by allowing expressions to be inserted, updated, and deleted without changing the application and providing a results set that can be manipulated in the same SQL statement, for instance to order or group results. Storage of expressions as data also enables large expression sets to be indexed for performance. In contrast, a procedural approach stores results in a temporary table that must be queried for further processing, and those expressions cannot be indexed. As both Gryphon and Scribe are not database oriented approaches, indexing is not possible as in expressions.

2.2 DIFFERENCES BETWEEN ORACLE'S AND OUR APPROACH

Though the expression filter from Oracle 10G is similar to the expression concept in terms of evaluation from our approach, there is one main difference in terms of complexity. Oracle 10G's expression filter is applied over a single table, whereas, our approach of Evaluate operator can be applied over multiple tables as shown by the following example.

Example:

Let us assume a web application where there are two tables Car and Dealer. One table contains information about cars, including car price, car model, car year etc. (An example is shown in table 2). Another table contains information about car dealers, including dealer name, address, rating etc. (An example is shown in table 3). If a user is interested in buying a car which is around \$10000 but he wants to buy from a good dealer, an expression to cater such a user's interest would involve predicates that access data in both the tables car and dealer , and later on when we apply the EVALUATE operator, it would be across both the tables. For example in that case the expression would look something like this

Car.Price = 10000 AND Dealer.Rating = 10

#	Model	Year	Price	Color	Mileage
1	Taurus	1999	10000	Blue	40000
2	Toyota	2000	13000	Black	20000
3	BMW	2001	20000	Silver	23000

Table 2 Car Table

#	Name	Address	Zip	Rating	Cars
1	Toyota	1, A	10172	7	400
2	Auto Zeal	2, B	10183	5	200
3	Car Zone	3, C	11289	10	125

Table 3 Dealer Table

The above expression is with the assumption that a rating of 10 is the maximum rating that can be assigned to a dealer.

One other difference between Oracle's expression filter and this approach of expression datatype lies in terms of implementation. In our approach, the expressions are stored in separate tables as opposed to storing them in a column of the same table. This might be thought of as a downside, because by storing expressions in a separate expression table, additional join can be required between the expression table and the table with the user/customer info, *but*, having the expressions in separate table will be a more Normalized form of representation because different users might be interested in the same data item that might repeat many times in the user interests table in Oracle's approach.

3. THE EXPRESSION DATATYPE AND EXPRESSION EVALUATION

This chapter describes the structure and semantics of expression datatype. The chapter begins by providing the grammar for an expression in the BNF form. Evaluation semantics are explained next which is followed by explaining how expressions are evaluated to true with an algorithm.

3.1 EXPRESSION GRAMMAR

Any expression can be said to be composed of one or many atomic expressions which are called Predicates. The BNF representation of the expression datatype is shown below.

Expression ::= Predicate | Predicate AND Expression

Predicate ::= Identifier Operator Constant | Constant Operator Identifier

Operator ::= < | > | = | <= | >=

Identifier ::= Table.Column

Example:

Let us consider the following expression

Car.Year = 2000 AND Car.Price < 20000

The above expression can be represented in the BNF form as follows. For ease of understanding the grammar representation of the expression is shown from the identifier level.

Identifier1: Car.Year

Identifier2: Car.Price

Operator1: =

Operator2: <

Constant1: 2000

Constant2: 20000

As per the grammar, Predicate1: Identifier1 Operator1 Constant1

Representing the our example in predicate form we have

Predicate1: *Car.Year = 2000*

Similarly we have Predicate 2 as

Predicate2: *Car.Price < 20000*

Also as per grammar, Expression: Predicate1 *AND* Expression

And bringing in the Predicate 2 gives, Expression = Predicate1 *AND* Predicate2 which is simplified as Expression: *Car.Year = 2000 AND Car.Price < 20000*

Hence we have represented our sample expression in BNF form.

3.2 SEMANTICS OF EVALUATION

The *EVALUATE* operator is used to evaluate a data item against the stored expressions. The *EVALUATE* operator accepts a set of data item constituents in a data item, and those data item constituents are evaluated on all the stored expressions and in turn predicates. This operator returns a list of stored expressions that were evaluated to true against the provided data item.

If there are more than one predicates in an expression, all predicates have to be evaluated to true for the expression to be evaluated to true.

Example:

Consider the expression

Car.Year > 1995 AND Car .Year < 2000

In this expression, there are two predicates.

Consider this expression is evaluated against the following data item *Car.Year = 1998*

In this case the expression would be evaluated to true because both the predicates are evaluated to true.

Let us consider evaluation of one more data item

EVALUATE Car.Year = 2005

Now, even though the first predicate is evaluated to true, the second predicate is false and hence the expression as a whole would be evaluated to false.

3.3 EVALUATION CASES

Based on the above discussion, we could frame three possibilities of evaluation at the predicate level and at the expression level. They are given as follows.

3.3.1 Predicate Level

At the predicate level, there are three possible outcomes when each predicate of an expression is evaluated for a data item.

- **CASE 1 – PREDICATE EVALUATES TO TRUE**

In this case a) the data item contains a constituent matching the identifier in the predicate, and b) the predicate evaluates to true for the value in this data item constituent.

Example:

Predicate: *Car.Year > 1995*

Data item constituent: *Car.Year = 1999*

- **CASE 2 – PREDICATE EVALUATES TO FALSE**

In this case a) the data item contains a constituent matching the identifier in the predicate, and b) the predicate evaluates to false for the value in this data item constituent.

Example:

Predicate: *Car.Year > 1995*

Data item constituent: *Car.Year = 1992*

- **CASE 3 – CANNOT EVALUATE PREDICATE**

In this case the data item does not contain any constituent that matches the identifier in the predicate.

Example:

Predicate: *Car.Year > 1995*

Data item: *Car.Model = 'TAURUS' AND Car.Price = 20000.*

3.3.2 Expression Level

The expression is a combination of one or more predicates. Therefore at the expression level, there are three cases also. They are explained as follows.

1. Expression evaluates to true if *ALL* the predicates in the expression evaluate to true.
2. If at least one predicate in an expression evaluates to false, then the expression evaluates to false.
3. If at least one predicate in an expression cannot be evaluated, then the expression evaluates to false.

If we consider expressions with two predicates, the above can be enumerated as follows. Note: ‘?’ refers to predicates that cannot be evaluated.

#	Predicate 1 Evaluates to	Predicate 2 Evaluates to	Expression Evaluates to
1	T	T	T
2	T	F	F
3	F	T	F
4	F	F	F
5	T	?	F
6	F	?	F
7	?	T	F
8	?	F	F

Table 4 Evaluation Possibilities

3.4 ALGORITHM

The algorithm developed for evaluation of expressions is as follows. First the given data item was taken and checked against all the predicates of all the conditional expressions to get a list of predicates that are evaluated to true. So now, irrespective of the expressions we have a set of predicates that are evaluated to true. Then, the list of predicates is compared with the expressions to get the list of expressions that have those predicates evaluated to true. All of the predicates in an expression have to be present in the list, which contains the list of predicates that are evaluated to true. So the resultant set is a set of expressions that are evaluated to true. The evaluation can be expressed in the following sequence of steps.

1. Parse the data item to split them to individual data item constituents
2. For each data item constituent
 - find the predicates that evaluate to true and store them in an array called ‘predicate out’ array

3. Traverse through all expressions

- If all the predicates of an expression are present in the 'predicate out' array, that expression evaluates to true.
- Otherwise, the expression evaluates to false.

4. IMPLEMENTATION OF EXPRESSION DATATYPE

In order to implement the expression data type and to develop the *EVALUATE* operator, a mini *DBMS* was implemented in C. The *DBMS* supports few features that are essential for the testing of the expression data type and the *EVALUATE* operator.

4.1 DATA STRUCTURE

The data structure as such is simple because only a few features of a real *DBMS* were implemented. Provisions are there to create a new database and to work on an existing database. Tables and schemas are preserved for each database. All the table information is stored in flat files with tab delimiters. All user table information is stored in a table called *sys_tab*. This is again a flat file with the same data structure. The other two tables that are created when a database is created are the Expression table and the Predicate table. These tables are explained under section 4.3.

4.2 MINI DBMS - FEATURES

Expressions, or in general data, has to be inserted, deleted or selected into and from the predicate tables and the expression tables for various purposes of testing and building the *EVALUATE* operator. For this purpose some features were implemented. The features that are implemented are: create a new database, work on an existing database, Create Table, Insert, Select and Delete. Let's look into the details of a few.

Create Table:

The create table feature creates a table with an entry in the sys_tab table. This feature does not allow duplicate tables in a database. So every time a new table is created, the name of the new table is validated against the entries in the sys_tab table. The code snippet for create table is shown.

```
if (strcmp (arr[0], "create")==0)    {
    table[0]='\0';
    strcpy(table,arr[2]);
    strcat(table, ".txt");
    sys=fopen("sys_tab.txt", "a+");
    i=0;
    flag=0;
    while (fscanf(sys, "%s", temp[i]) != EOF) {
        if(strcmp(temp[i],table)==0){
            printf("\n Table already exists. ");
            flag=1;
        }
        i++;
    }
    fflush(sys);
    fclose(sys);
    if(flag==0)    {
        sys=fopen("sys_tab.txt", "a+");
        fprintf(sys, "%s\t\n", table);
        tb=fopen(table, "a+");
        for(i=4; i<ncmd; i+=3)
            fprintf(tb, "%s\t", arr[i]);
        fprintf(tb, "\n");
        for(i=5; i<ncmd; i+=3)
            fprintf(tb, "%s\t", arr[i]);
        fprintf(tb, "\n");
        fclose(tb);
        printf("table created");
    }
    fflush(sys);
}
```

Example:

Let us consider an example where we have to create a table with two columns 'id' and 'name'. In the mini DBMS, the creation syntax is the same as any SQL create function. The example is shown below.

```
CREATE TABLE employee (ID INT, NAME VARCHAR);
```

Select

The 'select' feature is a typical select feature with limited options. There are six cases with which the select statement is built. They are listed below.

- Select *
 1. Where clause contains '='
 2. Where clause contains '<' or '<='
 3. Where clause contains '>' or '>='
- Select columns
 4. Where clause contains '='
 5. Where clause contains '<' or '<='
 6. Where clause contains '>' or '>='

Examples of selects from the previously created employee are shown below.

- *SELECT * FROM Employee WHERE NAME = 'JOHN'*
- *SELECT * FROM Employee WHERE ID < 1000*
- *SELECT NAME FROM Employee WHERE ID = 30*

4.3 STORING EXPRESSIONS: PREDICATE AND EXPRESSION TABLES

This section describes how expressions are stored as predicates and how they are referenced in forms of table rows. User's Interests are considered as sets of expressions. Expressions are said to be composed of one or more predicates. In this database, the predicates are stored in a table called the *PREDICATE TABLE*, and the expressions, which compose the predicates, are stored in another table called the *EXPRESSION TABLE*, with references to the predicates in the predicate table making it a kind of foreign key relationship.

The data model diagram for the expression datatype, which shows the relation between the Predicate table and the Expression table, is shown below.

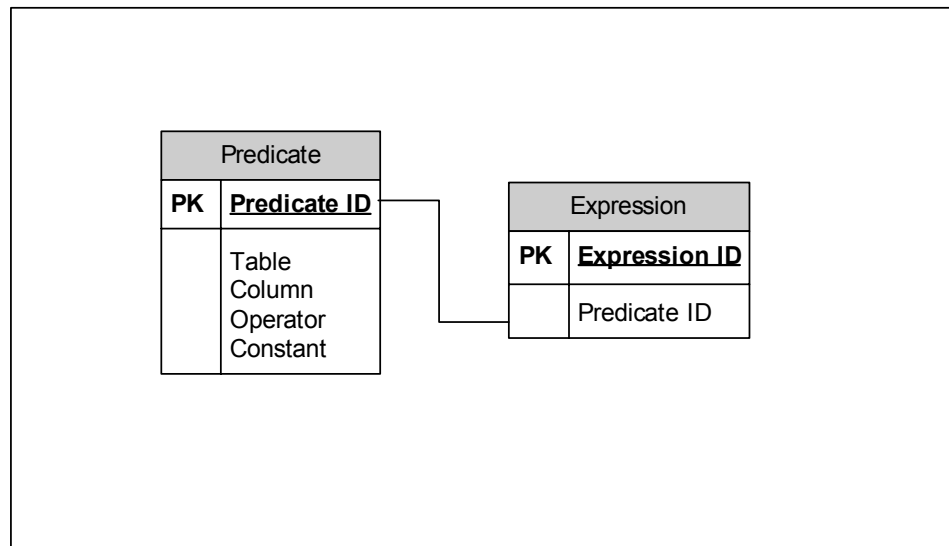


Figure 1 Data model – Expression datatype

The predicate table contains the following fields.

- Predicate ID
- Table
- Column

- Operator
- Constant

The expression table contains the following fields.

- Expression ID
- Predicate ID

An expression may consist of more than one predicate which implies that more than one row in the expression table are part of the same expression.

Example:

For example let us consider the following two expressions with different number of predicates, one with two and the other three. In this example, there are two tables Car and Dealer that are involved. Let's say that Car has columns such as Model, Year, Price, Color etc and Dealer table has columns such as Name, Address, Rating, etc.

1. *Car.Model = 'Taurus' AND Car.Year = 1998*
2. *Car.Model = 'Mercedes' AND Car.Year = 1998 AND Dealer.Rating = 10*

These two expressions are stored in the predicate table and the expression table as follows.

Predicate ID	Table	Column	Operator	Constant
1	Car	Model	=	'Taurus'
2	Car	Year	=	1998
3	Car	Model	=	'Mercedes'
4	Dealer	Rating	=	10

Table 5 Predicate Table

Expression ID	Predicate ID
1	1
1	2
2	3
2	2
2	4

Table 6 Expression Table

In the above example, there are two expressions one with two and the second with three predicates that are stored. Hence there are totally five predicates when we consider both the expressions. Even though there are totally five predicates in the two expressions, only four entries are entered in the predicate table. This is because the predicate with predicate id 2 is repeating in both the predicates and is **stored only once**. In other words, **predicates that are common among different expressions are stored only once**.

As explained before, more than one table can be involved in this approach of expressions. In other words, expressions **can be specified over multiple tables**.

4.2 PARSING THE EXPRESSIONS - LEX PARSER

A parser was developed using the LEX tool to parse the expressions and separate the tokens to be stored in the predicate table. The tokens were table, column, operator and constant. The parser was built in such a way that the expressions can be reversed, i.e. the column name can come after the constant. For example

Car.Model = 'Taurus'

(or)

'Taurus' = Car.Model

Initial research was done on Lex parser through various books and papers. One such book is [6]. The parser contains various segments, which check for a particular group of literals. One such segment checks for alphabetical words and if there are any, stores the words in an array. The code segment is shown below.

```

[a-zA-Z]*\.[a-zA-Z]+    {
for (i=0;i<strlen(yytext);i++)
    if (yytext[i]!='.')
        break;
    else
        temptable[i]=yytext[i];
temptable[i]='\0';
k=0;
for(j=i+1;j<strlen(yytext);j++)
{
    tempcolumn[k]=yytext[j];
    k++;
}
tempcolumn[k]='\0';
strcpy(column[v],tempcolumn);
strcpy(table[u],temptable);
u++;
v++;
}

```

If there are the words 'and' or 'AND' then the number of predicates are increased.

```

"AND" |
"and" {
    prid++;}

```

The operators checked are as follows.

```

"=" |
"<" |
">" |
"<=" |

```

```

">=" {
    strcpy(operator[w],yytext);
    w++;
}

```

There are some special words such as *EVALUATE*, *INSERT*, *EXPRESSION* etc, which are also checked, and corresponding actions are taken. The main token which is checked is the ‘;’, which denotes the end of a query or expression. Therefore if a ‘;’ is found then that is where the actual processing starts to store the expression and predicates.

4.3 ENTERING SAMPLE DATA - THE SCRIPT FILE

In order to populate the expression table and the predicate table with sample values a script was written. This script generates the given number of predicates and accordingly expressions with provisions of sample values as input. With the sample values, random combinations are generated to give a complete test set.

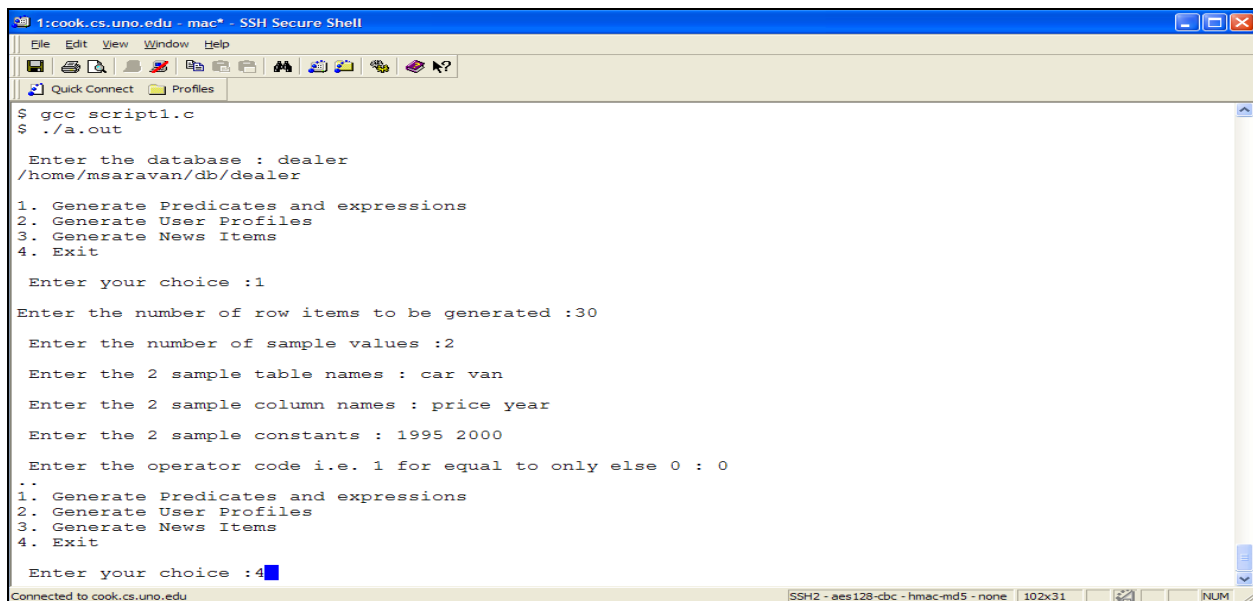
The script file is named as script1.c and the compilation and a sample run is shown in Fig 2. The predicate table and the expression table generated as a result of the script file are also shown in Fig 3 and 4 respectively.

The expression file has predicate ids that are generated in the predicate tables. Also there are different numbers of predicates in an expression; i.e. some expressions have one predicate, some two, some three and so on.

The options that are present in under the script file are

1. Generate Predicates and Expressions
2. Generate user interests
3. Generate news items.
4. Exit

Option 1 generates predicates and expressions and populates them to the predicate and expression tables correspondingly. Options 2 and 3 are used to populate user and user_interests tables respectively which are explained in the next chapter.



```
1:cook.cs.uno.edu - mac* - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles
$ gcc script1.c
$ ./a.out
Enter the database : dealer
/home/msaravan/db/dealer
1. Generate Predicates and expressions
2. Generate User Profiles
3. Generate News Items
4. Exit
Enter your choice :1
Enter the number of row items to be generated :30
Enter the number of sample values :2
Enter the 2 sample table names : car van
Enter the 2 sample column names : price year
Enter the 2 sample constants : 1995 2000
Enter the operator code i.e. 1 for equal to only else 0 : 0
..
1. Generate Predicates and expressions
2. Generate User Profiles
3. Generate News Items
4. Exit
Enter your choice :4
```

Figure 2 Script File

The following figure shows some inserted values in the predicate table as a result of executing the script file option 1.

pred_id	table	column	operator	constant
1	car	price	<=	1995
2	van	price	<	2000
3	van	price	=	1995
4	van	year	<=	2000
5	car	year	<=	1995
6	car	price	<=	2000
7	van	price	<	1995
8	van	year	<	1995
9	van	price	=	2000
10	car	price	=	1995
11	van	year	=	1995
12	car	year	>	1995
13	car	year	>	2000

Figure 3 Predicate Table Screenshot

And those predicates are created as part of expressions, which are inserted into the expression table.

exp_id	pred_id
1	1
2	2
2	3
2	4
3	5
3	6
3	7
4	8
4	9
5	7
5	10
6	2
6	11
6	2
7	12
7	13
8	3
8	2
8	11
9	1
9	6
10	8
10	8
10	2
11	11
11	9
11	4
12	3
12	8
13	7

Figure 4 Expression Table Screenshot

4.4 EXECUTION OF EVALUATION

The following screenshots show the compilation and execution of the programs. The first screen below shows the directory structure before compilation, which has the three program files script1.c, db.c and the lex parser, parse.l.

First in order to create a new database and start entering our commands, we compile the db.c program using gcc compiler. Then the lex parser is compiled to form the intermediate file, which is then compiled using the gcc compiler to get the executable object file “first”.

A list of the files after compilation is shown which includes the executable a.out for the db.c and the intermediate C file lex.yy.c, which contains embedded lex file and the executable compiled parser file that we created, first.

```
$ ls -l
total 72
-rw-r--r-- 1 msaravan cscistu 11924 Jan 23 22:05 db.c
-rw-r--r-- 1 msaravan cscistu 7661 Jan 22 09:38 parse.l
-rw-r--r-- 1 msaravan cscistu 16258 Jan 23 22:13 script1.c
$ gcc db.c
$ ls -l
total 102
-rwxr-xr-x 1 msaravan cscistu 14700 Jan 27 21:35 a.out
-rw-r--r-- 1 msaravan cscistu 11924 Jan 23 22:05 db.c
-rw-r--r-- 1 msaravan cscistu 7661 Jan 22 09:38 parse.l
-rw-r--r-- 1 msaravan cscistu 16258 Jan 23 22:13 script1.c
$
$ lex parse.l
$ gcc lex.yy.c -o first -ll
$ ls -l
total 190
-rwxr-xr-x 1 msaravan cscistu 14700 Jan 27 21:35 a.out
-rw-r--r-- 1 msaravan cscistu 11924 Jan 23 22:05 db.c
-rwxr-xr-x 1 msaravan cscistu 20744 Jan 27 21:40 first
-rw-r--r-- 1 msaravan cscistu 22935 Jan 27 21:39 lex.yy.c
-rw-r--r-- 1 msaravan cscistu 7661 Jan 22 09:38 parse.l
-rw-r--r-- 1 msaravan cscistu 16258 Jan 23 22:13 script1.c
$
```

Figure 5 Compiling the Programs

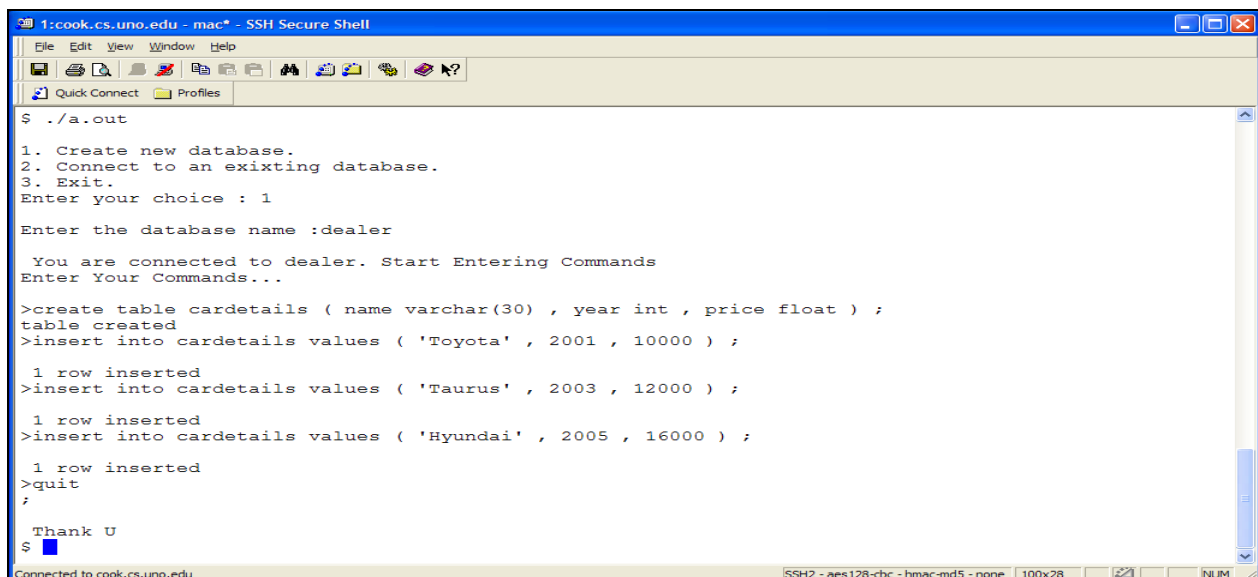
Fig 7 shows the file structures after creating a new database dealer. We can see that by default three files are created (in this case considered tables).

The three tables are

- Sys_tab
- Exp
- Predicate

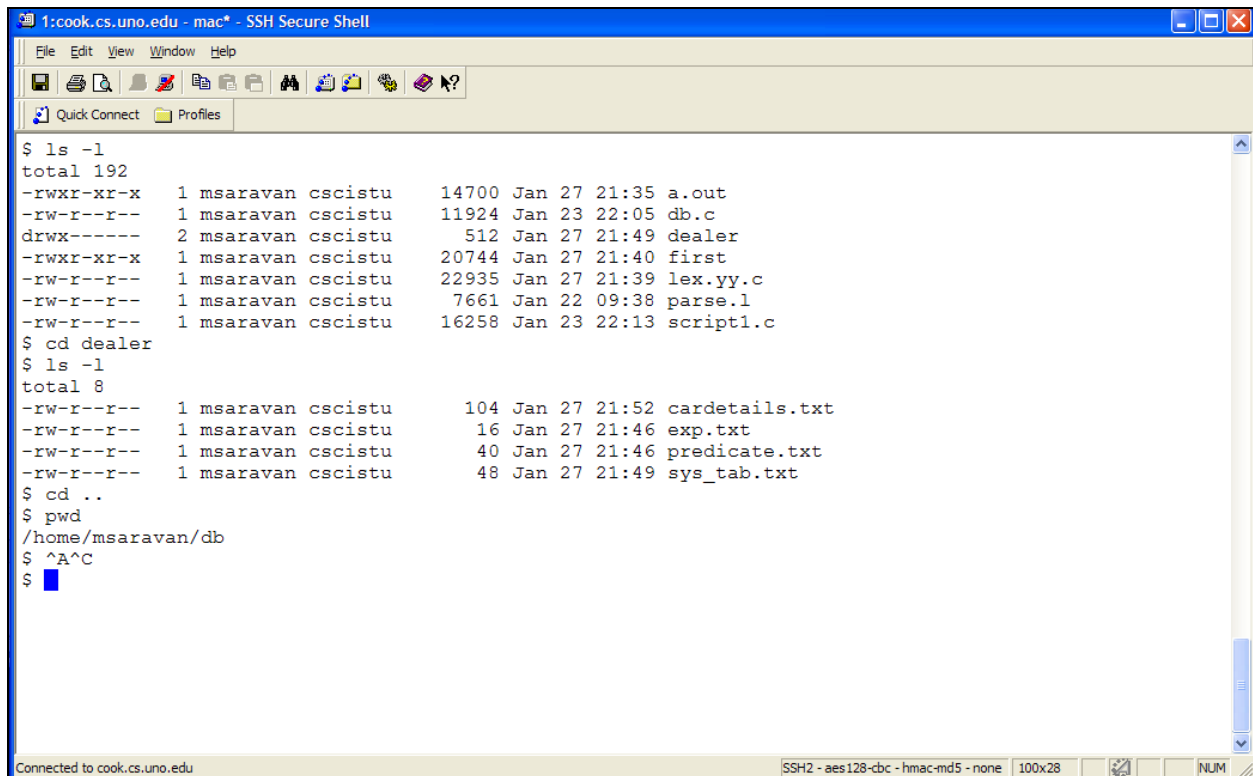
The sys_tab table has information about all the tables in that particular database. The exp table is used to store the expressions and the predicate table is used to store the predicates. We can also see another table cardetails, which we created. Once we create the table cardetails, an entry will be populated in sys_tab file with the table name cardetails.

Fig 8 shows the various contents of the sys_tab, exp, predicate and the cardetails tables.



```
1:cook.cs.uno.edu - mac* - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles
$ ./a.out
1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 1
Enter the database name :dealer
You are connected to dealer. Start Entering Commands
Enter Your Commands...
>create table cardetails ( name varchar(30) , year int , price float ) ;
table created
>insert into cardetails values ( 'Toyota' , 2001 , 10000 ) ;
1 row inserted
>insert into cardetails values ( 'Taurus' , 2003 , 12000 ) ;
1 row inserted
>insert into cardetails values ( 'Hyundai' , 2005 , 16000 ) ;
1 row inserted
>quit
;
Thank U
$
```

Figure 6 *Executing db.c*



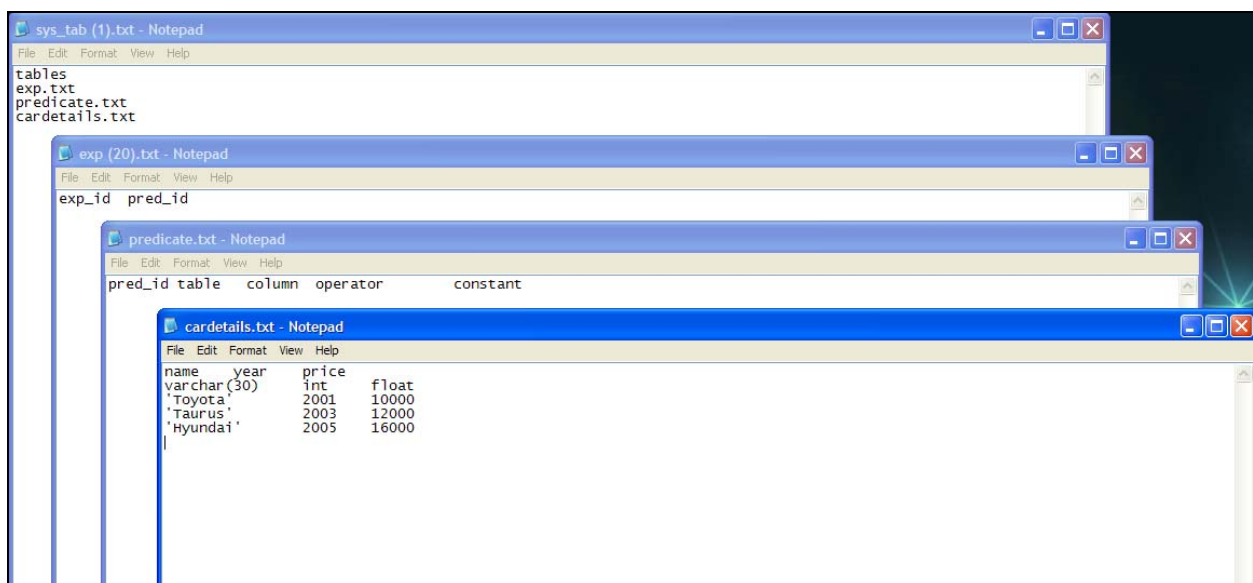
The image shows an SSH Secure Shell window titled "1:cook.cs.uno.edu - mac* - SSH Secure Shell". The window contains a terminal session with the following commands and output:

```
$ ls -l
total 192
-rwxr-xr-x  1 msaravan cscistu 14700 Jan 27 21:35 a.out
-rw-r--r--  1 msaravan cscistu 11924 Jan 23 22:05 db.c
drwx-----  2 msaravan cscistu   512 Jan 27 21:49 dealer
-rwxr-xr-x  1 msaravan cscistu 20744 Jan 27 21:40 first
-rw-r--r--  1 msaravan cscistu 22935 Jan 27 21:39 lex.yy.c
-rw-r--r--  1 msaravan cscistu  7661 Jan 22 09:38 parse.l
-rw-r--r--  1 msaravan cscistu 16258 Jan 23 22:13 script1.c
$ cd dealer
$ ls -l
total 8
-rw-r--r--  1 msaravan cscistu  104 Jan 27 21:52 cardetails.txt
-rw-r--r--  1 msaravan cscistu   16 Jan 27 21:46 exp.txt
-rw-r--r--  1 msaravan cscistu  40 Jan 27 21:46 predicate.txt
-rw-r--r--  1 msaravan cscistu  48 Jan 27 21:49 sys_tab.txt
$ cd ..
$ pwd
/home/msaravan/db
$ ^A^C
$
```

The status bar at the bottom indicates "Connected to cook.cs.uno.edu" and "SSH2 - aes128-cbc - hmac-md5 - none 100x28 NUM".

Figure 7 *Directories and Files*

Files created after creating a new database are shown in the above figure. The files created are the sys_tab, expression, predicate and car details.



The image shows four overlapping Notepad windows displaying the contents of files created in the previous figure:

- sys_tab (1).txt - Notepad**:

```
tables
exp.txt
predicate.txt
cardetails.txt
```
- exp (20).txt - Notepad**:

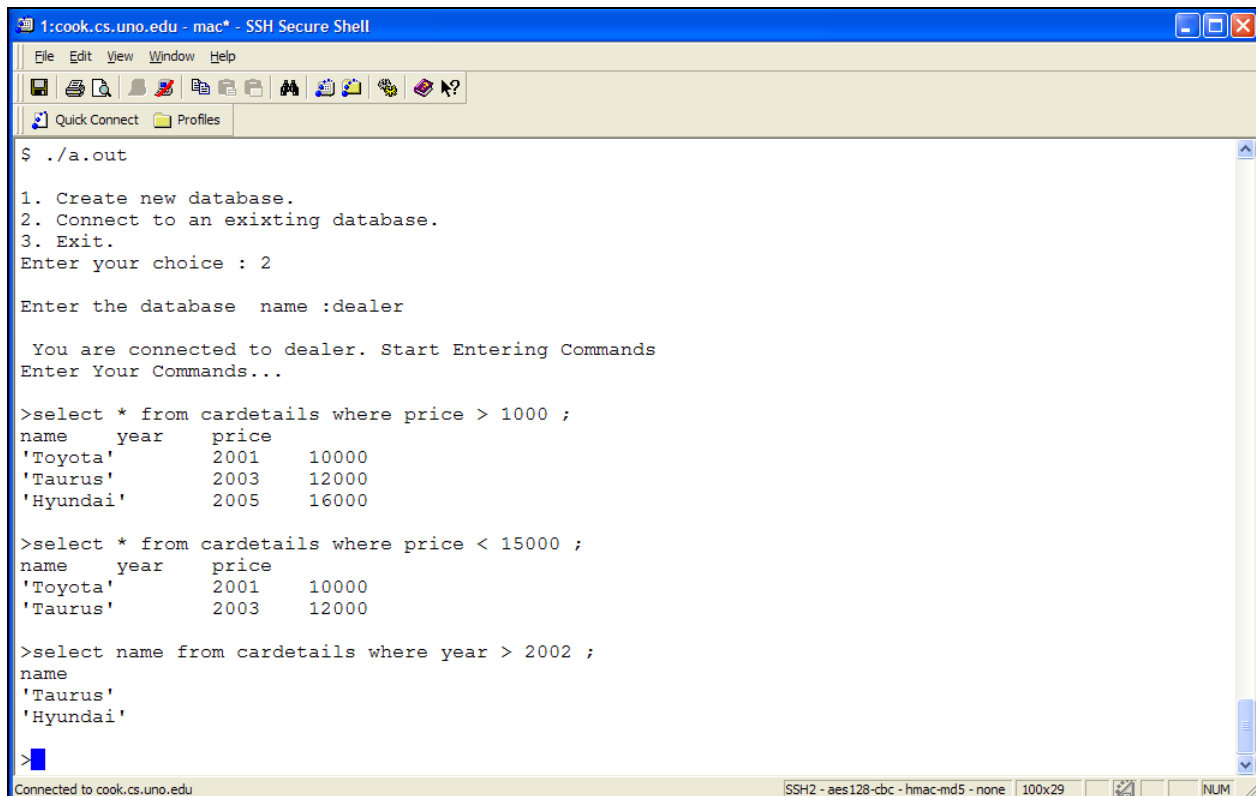
```
exp_id  pred_id
```
- predicate.txt - Notepad**:

```
pred_id table  column  operator  constant
```
- cardetails.txt - Notepad**:

name	year	price
varchar(30)	int	float
'Toyota'	2001	10000
'Taurus'	2003	12000
'Hyundai'	2005	16000

Figure 8 *Tables Contents after the run*

The following screenshot shows the select statement feature in the mini DBMS. The various options shown are selecting data using wildcards, using column names and using various operators in the condition clause.



```
1:cook.cs.uno.edu - mac* - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles

$ ./a.out

1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 2

Enter the database name :dealer

You are connected to dealer. Start Entering Commands
Enter Your Commands...

>select * from cardetails where price > 1000 ;
name    year    price
'Toyota' 2001    10000
'Taurus' 2003    12000
'Hyundai' 2005    16000

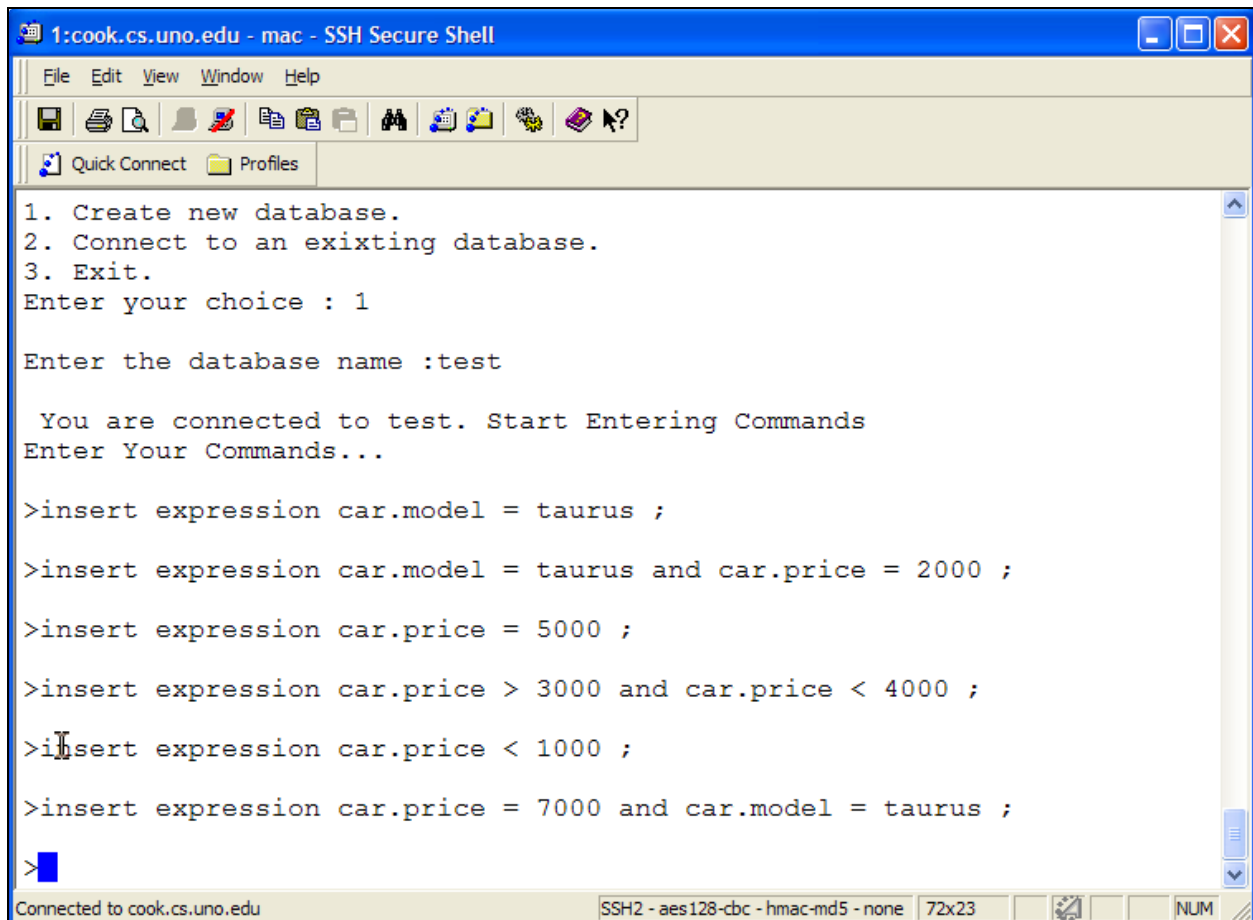
>select * from cardetails where price < 15000 ;
name    year    price
'Toyota' 2001    10000
'Taurus' 2003    12000

>select name from cardetails where year > 2002 ;
name
'Taurus'
'Hyundai'

>
```

Figure 9 Select statement

Some execution examples of the select statements are shown in the figure 9. The examples cover relational operators, wildcards and individual column selects.



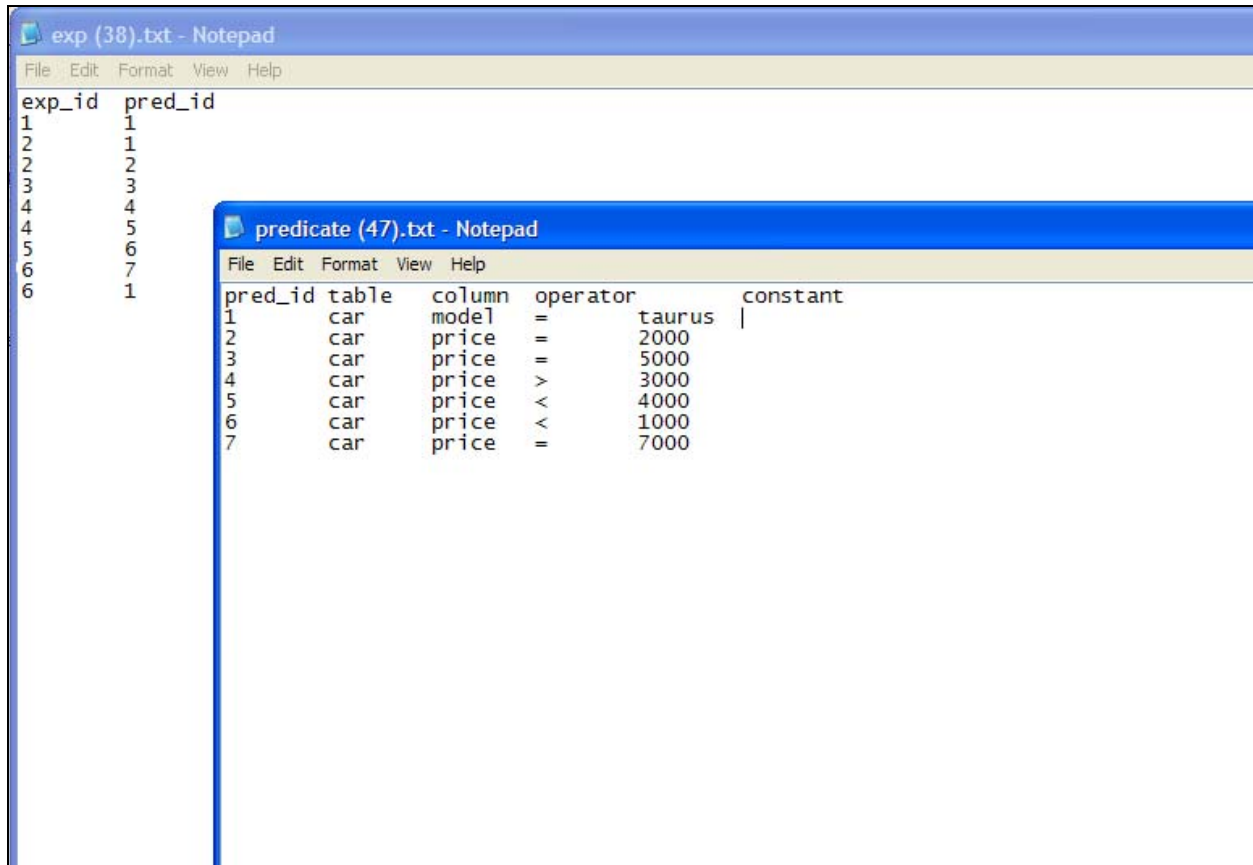
```
1:cook.cs.uno.edu - mac - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles
1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 1
Enter the database name : test
You are connected to test. Start Entering Commands
Enter Your Commands...
>insert expression car.model = taurus ;
>insert expression car.model = taurus and car.price = 2000 ;
>insert expression car.price = 5000 ;
>insert expression car.price > 3000 and car.price < 4000 ;
>insert expression car.price < 1000 ;
>insert expression car.price = 7000 and car.model = taurus ;
>
```

Figure 10 *Creating Expressions*

Insert statement, which is also a part of the mini DBMS is shown in figure 10. Insert statement can also insert expressions. In that case the expression is broken down into individual predicates and the predicates are inserted into the predicate table and the expressions are inserted in expression table. The lex parser is used for parsing.

In Fig 10, the predicate Car.Model = Taurus repeats thrice in expressions 1, 2 and 6. But still only one is stored as shown in the Fig 11. In the predicate table this is represented as predicate id 1. In the expression table, Predicate id 1 is present in three places over multiple expressions.

The expressions and predicates from the back end is shown in the following figure



The image shows two overlapping Notepad windows. The top window, titled 'exp (38).txt - Notepad', contains a table with two columns: 'exp_id' and 'pred_id'. The bottom window, titled 'predicate (47).txt - Notepad', contains a table with five columns: 'pred_id', 'table', 'column', 'operator', and 'constant'.

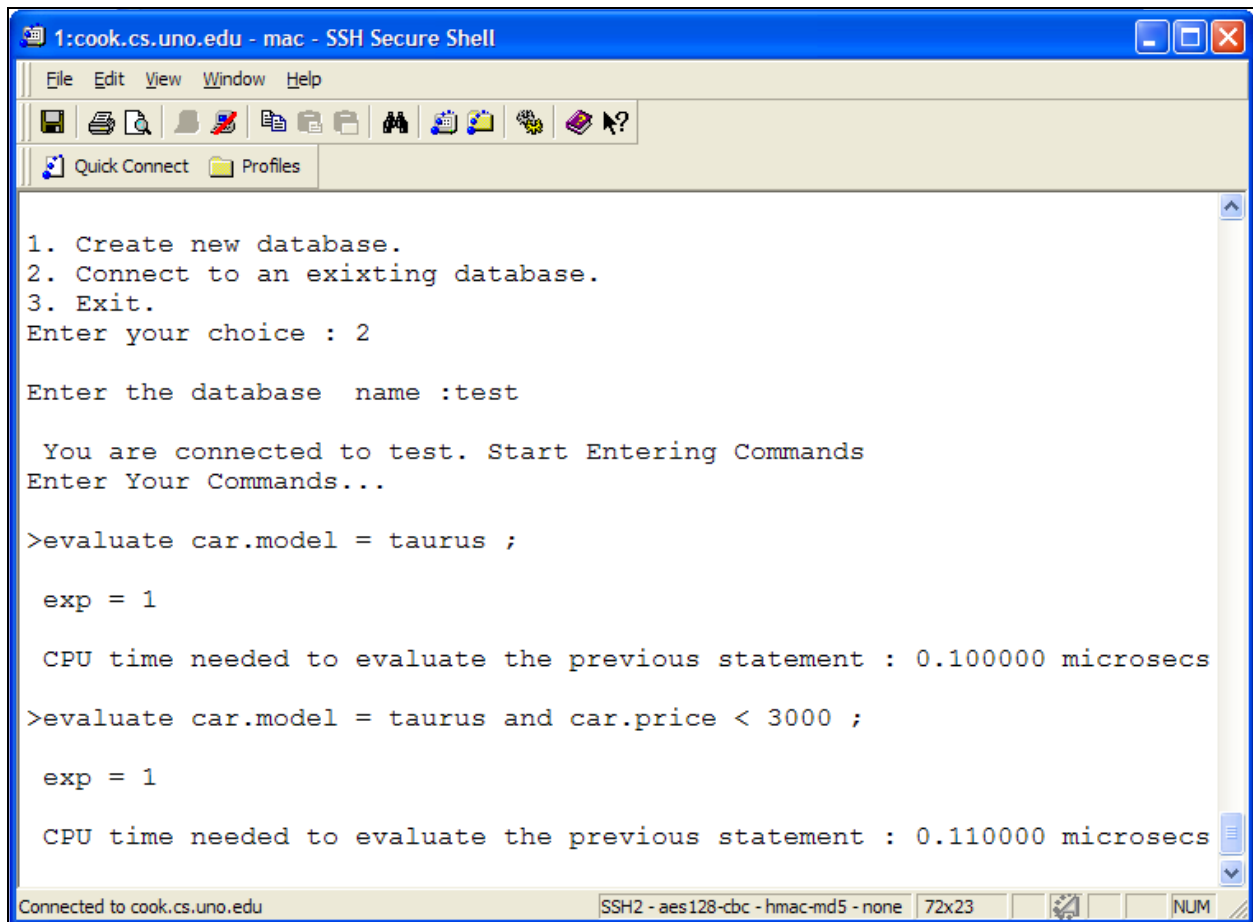
exp_id	pred_id
1	1
2	1
2	2
3	3
4	4
4	5
5	6
6	7
6	1

pred_id	table	column	operator	constant
1	car	model	=	taurus
2	car	price	=	2000
3	car	price	=	5000
4	car	price	>	3000
5	car	price	<	4000
6	car	price	<	1000
7	car	price	=	7000

Figure 11 Table entrees after insertions

Having shown screenshots of table creation, selection of data, insertions (in Fig 10) etc, we now move on to expression evaluation. The following two screenshots shows how to evaluate expressions under various conditions and against different data items.

The following screenshot (Figure 12) shows an evaluation for the data item *Car.Model* = *Taurus*. The expressions that have predicates that match the data item are 1, 2 and 6. Even though 2 and 6 have the predicate *Car.Model* = *Taurus*, those expressions are not evaluated to true because as per rule, “all predicates in an expression” have to be evaluated to true for the expression to be evaluated to true. Hence only expression 1 is evaluated to true.

The image is a screenshot of a terminal window titled "1:cook.cs.uno.edu - mac - SSH Secure Shell". It shows a menu bar with "File", "Edit", "View", "Window", and "Help". Below the menu bar is a toolbar with various icons. The main area of the window contains the following text:

```
1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 2

Enter the database name : test

You are connected to test. Start Entering Commands
Enter Your Commands...

>evaluate car.model = taurus ;

exp = 1

CPU time needed to evaluate the previous statement : 0.100000 microsecs

>evaluate car.model = taurus and car.price < 3000 ;

exp = 1

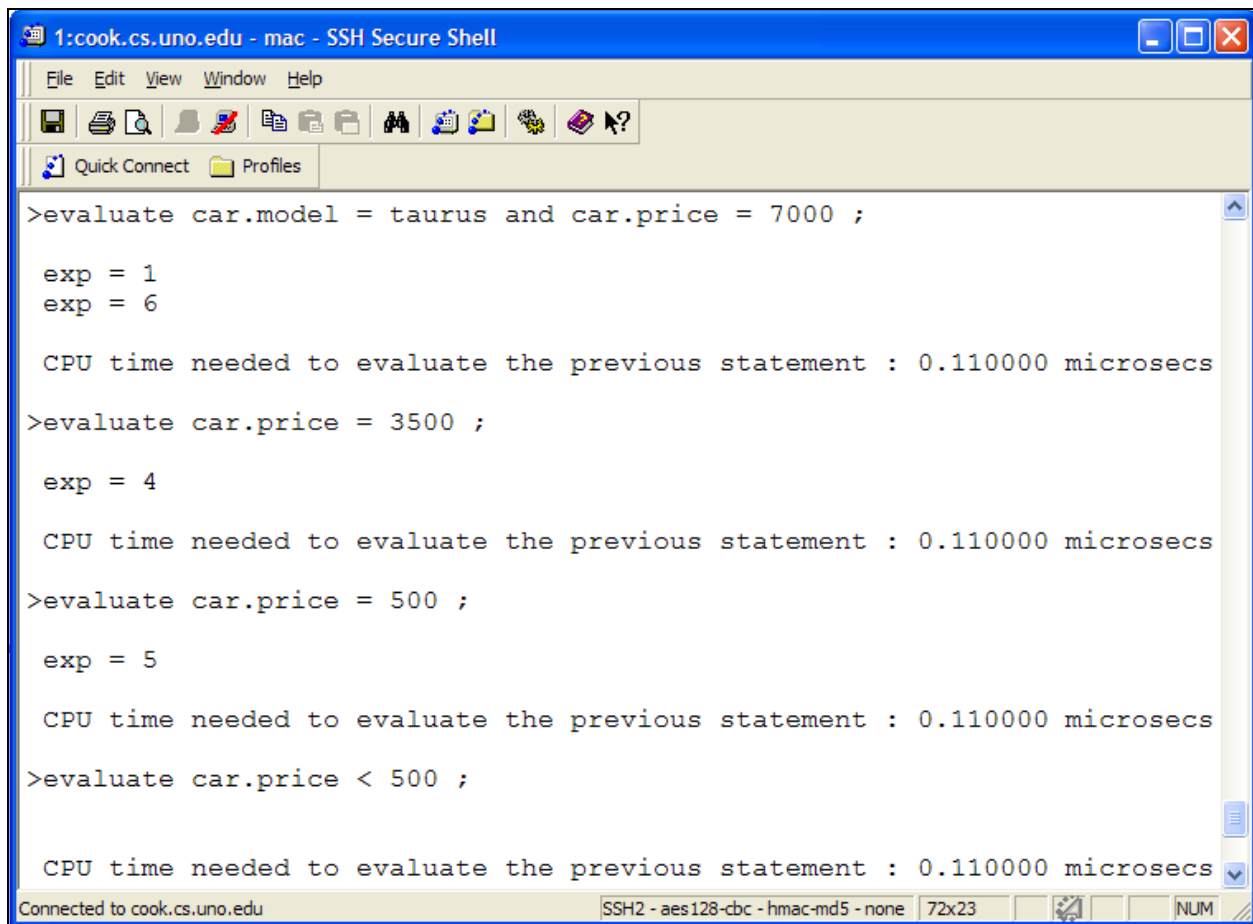
CPU time needed to evaluate the previous statement : 0.110000 microsecs
```

The status bar at the bottom of the window shows "Connected to cook.cs.uno.edu", "SSH2 - aes128-cbc - hmac-md5 - none", "72x23", and "NUM".

Figure 12 Evaluation 1

Similarly, the following screenshots (Figure 13) show some evaluations of additional data items along with expressions, which evaluate to true for the corresponding data items.

Additionally evaluation times in terms of microseconds are also shown for each evaluation.



The screenshot shows a terminal window titled "1:cook.cs.uno.edu - mac - SSH Secure Shell". The window has a menu bar (File, Edit, View, Window, Help) and a toolbar with various icons. Below the toolbar, there are tabs for "Quick Connect" and "Profiles". The main text area contains the following output:

```
>evaluate car.model = taurus and car.price = 7000 ;  
  
exp = 1  
exp = 6  
  
CPU time needed to evaluate the previous statement : 0.110000 microsecs  
>evaluate car.price = 3500 ;  
  
exp = 4  
  
CPU time needed to evaluate the previous statement : 0.110000 microsecs  
>evaluate car.price = 500 ;  
  
exp = 5  
  
CPU time needed to evaluate the previous statement : 0.110000 microsecs  
>evaluate car.price < 500 ;  
  
CPU time needed to evaluate the previous statement : 0.110000 microsecs
```

At the bottom of the window, a status bar shows "Connected to cook.cs.uno.edu", "SSH2 - aes128-cbc - hmac-md5 - none", "72x23", and "NUM".

Figure 13 *Evaluation 2*

5. SAMPLE APPLICATION: E-NEWS

Every Internet buff, on a daily basis has to browse quite a few web sites to get information/news on some of his areas of interest. It could be Sports, Music or even Information Technology. Time is a constraint that every person in this world has. So, obviously, it would be very nice to have a single point to get all the news a person needs to know daily, or whenever possible.

Mobile e-News (hereafter referred as e-News) is a Web Service based application that was developed for a Palm device. E-News was developed previously as part of a class project [12] in ‘**Topics in Mobile Computing**’. J2ME technology was the backbone of the application. Mobile e-News is an application that provides news that is updated quite often. The content of the news displayed depends on the user who is logged in. When users register themselves in the e-News website, they would provide their interests in different categories. When they login to the application from the mobile device, they would get updated news according to the registered categories.

The categories were

- Music
- Sports
- Education

Some of the interests under each category were Rock, Jazz and Hip Hop under music, Tennis, Basketball and Football under sports and UNIX, Java and C++ under education.

Notice that e-News application requires storing a user's interest and periodically evaluating this interest against news items. This application is thus an excellent candidate for use of expression data type.

In Section 5.1, the overall architecture of e-News application is described. Section 5.2 compares two approaches of implementing e-News. The first implementation doesn't use expression data type, while the second implementation makes use of the expression data type. Section 5.3 compares the two implementations in terms of expressivity and performance.

5.1 E-NEWS ARCHITECTURE

The architecture that lay behind developing e-News is shown in the following figure

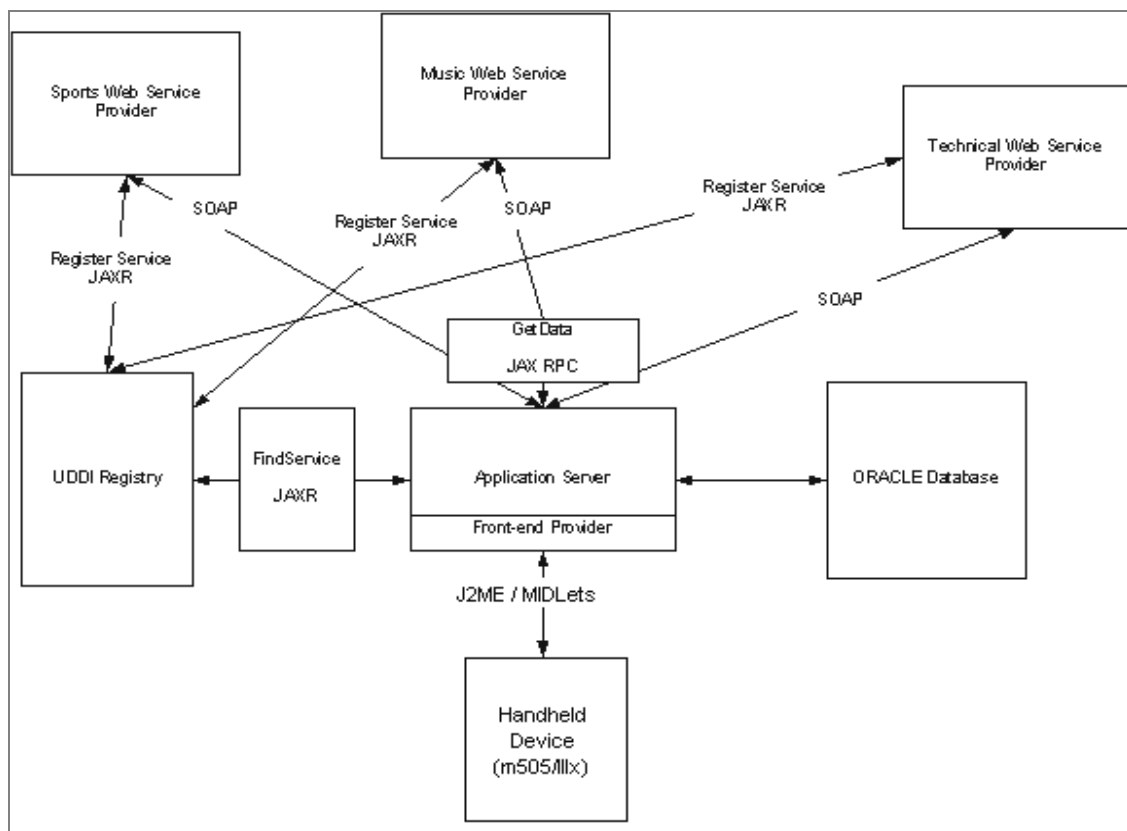


Figure 14 Mobile e-News - Architecture

The application was developed on a *Web Services Model*, using the architecture suggested by Sun Microsystems in the Java Web Services Developer Pack 1.2. The Application Server would communicate with a *UDDI Registry* to find out any relevant Information *Web Service Providers*. Once this is ascertained, the Servlets would communicate with various Web Services using SOAP and retrieve the relevant data before populating the GUI for the user to view. User information is stored in a simple database created in *ORACLE*.

5.2 SIMULATION OF E-NEWS WITH AND WITHOUT EXPRESSION DATATYPE

This section compares and contrasts two approaches to implement e-News. Both the approaches are not complete implementations of the e-News application. In both the approaches only those features of the application are implemented that are necessary to contrast the modeling of user interest and compare the performance. The first one, referred to as Before Approach is a simulation of e-News using regular database joins, i.e., without using expression datatype. The second approach referred to as After Approach is a simulation of e-News with expression datatype.

In both approaches the interests of users are stored in a table called `user_interest`. In the before approach, the user interest is a mapping between the user table which has all personal information about the user (explained later in detail) to three other tables which store information about the user interests by the use of regular database joins. In the after approach, the user interest is a mapping between the same user table, which has personal information about the user, and expression/predicate tables. Both these approaches are explained in detail in the later sections of this chapter.

5.2.1 Before Approach – Without Using Expression Datatype

We first describe how user interest is maintained and evaluated against the latest news without using expression data type. This approach is referred to as **Before Approach** and is similar to the database model used for the e-News class project.

In e-News class project, a first time user has to register his interests in the application. During registration, the user chooses his area of interests from a list of available categories. The available categories are music, sports, academics, etc. Within each category the user further specifies characteristics of items that are of interest to him. The user interest is stored in tables such as table, column, constant, user, user_interests etc. Details about these tables will be explained in the next section. The user also enters their profile information such as address. Other tables which were used are the ‘link’ table and the user ‘authentication’ table. Description of these tables is given below.

Table 7 is a sample ‘link’ table. This table has two columns ‘metadata’ and ‘URL’. The e-News application retrieves links to news items from different websites. URLs of these items are stored in the ‘URL’ column. Metadata about the item pointed to by the URL is stored in the ‘metadata’ column. This metadata is analogous to the data item which was already explained before. More than one URL in the ‘link’ table may have the same metadata. E.g., in the sample ‘link’ table there are two rows with metadata Subject.Sports = ‘Soccer.’ So if a user’s interest included soccer, then these two URLs will appear in sports section of the screen shown to him. Note the given URLs are just sample values and may not be up to date.

Metadata	URL
Subject.Music = 'Rock'	http://music.yahoo.com/read/news/35553567
Subject.Sports = 'Soccer'	http://sports.espn.go.com/sports/soccer/news/story?id=2571758
Subject.Sports = 'Soccer'	http://sports.espn.go.com/sports/soccer/wc/news/story?id=2569310
Car.Model = 'Taurus'	http://www.cars.com/go/search/modelid=185/model=Taurus
Car.Year = 2000	http://www.cars.com/go/search/year2000&
.....

Table 7 Sample Link Table

Table 8 is a sample 'authentication' table, which contains all password information for the users. This table has two columns 'user_id' and 'password'. The user ids map to the user ids in the user table.

User_ID	Password
1	abc
2	def
4	ghi
.....

Table 8 Sample Authentication Table

When a user logs on to e-News, first, authentication is performed by verifying the user id against the password in the authentication table. Next, user's interests are retrieved from the database. These interests are matched with the rows in the links table and corresponding news items are populated on the screen. This may be termed as "first time data retrieval".

Additionally, periodic requests are sent by the application to the web server to get more recent news and updated in the links table. Hence, when the user stays logged in the application for a considerable amount of time say till after the periodic link table refresh is done, and if the user refreshes his/her browser, he/she would see more updated news on their interest. This may be termed as "periodic data retrieval".

The tables links table and authentication table are functionally the same for both the approaches. Hence, those tables are irrelevant for the comparison and are not implemented in both the approaches.

The simulation of the before approach is done using DB2 as the database and C as the interface language with embedded SQL in the program.

5.2.1.1 Data Model

The ER diagram for the before model is shown in the figure.

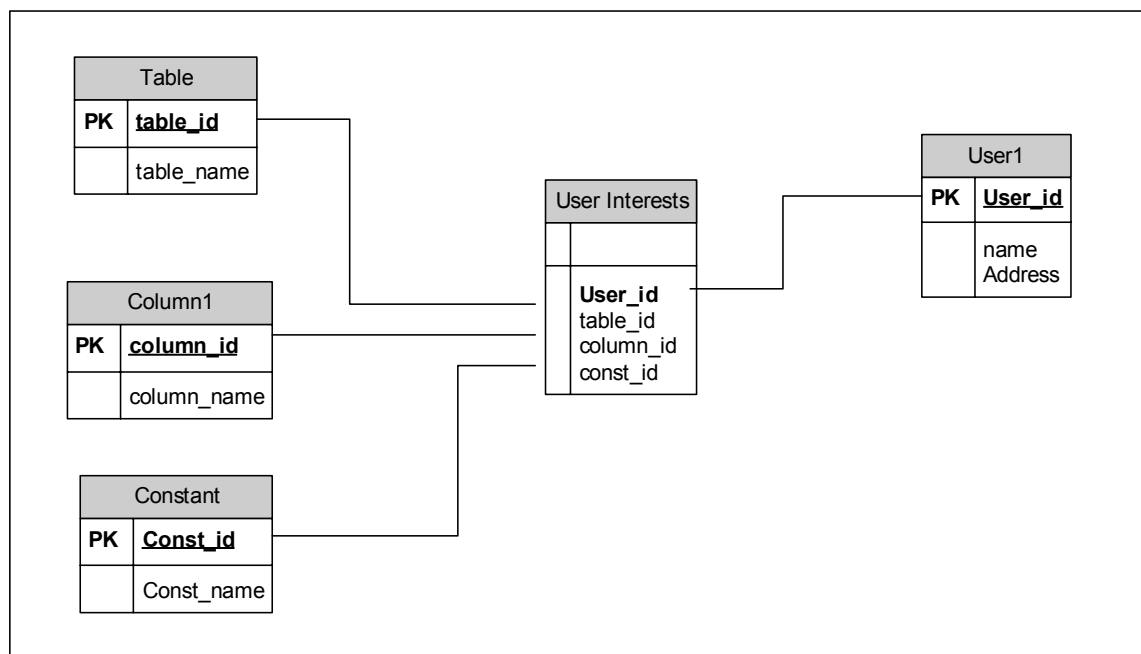


Figure 15 *e-News Architecture – Before Case*

Table Creation and Data Insertion

In order to explain a user interest, some sample data is entered and the statements used to create table and perform inserts are shown in the following paragraphs. The insert statements are used to create the user interests by making inserts to the following tables: table, col, constant, users and user_interests.

Table Creation SQLS

```
create table ls2user.tbl ( tbl_id varchar(20), tbl_name varchar(20));  
create table ls2user.col ( col_id varchar(20), col_name varchar(20));  
create table ls2user.const (const_id varchar(20), const_name varchar(20));  
create table ls2user.user1 ( user_id varchar(20), user_name varchar(20), user_address  
varchar(20));  
create table ls2user.user_interests ( user_id varchar(20), tbl_id varchar(20), col_id varchar(20),  
const_id varchar(20));
```

Table Insert SQLS

The insert statements are used to populate the user's interests. Various categories, columns, constants are populated in their respective tables. The unique id is also entered along with the values. Insertions into the 'user' table will have a list of users with their user ids. Finally, insertions into the table user_interest are done which populates mapping values from all other tables.

The insert statements create the user's interest by creating a mapping across the various tables. For example, the first the first user's interest is created for the user with user_id '1' ('john') who is interested in the news items with table_id as '2' ('subject'), col id as '4' ('music') and constant as '1' ('rock'). So in plain words, it means John is interested in rock music and wants all rock music related news.

The following insert statements populate the various tables that are available into the table called 'table'. Here the available tables are 'car' and 'subject'.

```
insert into ls2user.tbl values ('1','car');
```

```
insert into ls2user.tbl values ('2','subject');
```

The following insert statements populate the table called 'col', which literally are the attributes of the elements in the table 'table'. The various attributes in our example are model, price and year for car, and music, sports and acads for subject.

```
insert into ls2user.col values ('1','model');
```

```
insert into ls2user.col values ('2','price');
```

```
insert into ls2user.col values ('3','year');
```

```
insert into ls2user.col values ('4','music');
```

```
insert into ls2user.col values ('5','sports');
```

```
insert into ls2user.col values ('6','acads');
```

The following insert statements populate the table called 'const' which are the available values for the elements in the table 'col'. The various constants in our example are rock and jazz for music, soccer and cricket for sports java for acads and 2000 for price or year.

```
insert into ls2user.const values ('1','rock');
```

```
insert into ls2user.const values ('2','soccer');
```

```
insert into ls2user.const values ('3','java');
```

```
insert into ls2user.const values ('4','jazz');
```

```
insert into ls2user.const values ('5','cricket');
```

```
insert into ls2user.const values ('6','2000');
```

The following insert statements populate the table called ‘user1’ which creates the information regarding the registered users. For example, the first insert statement below states that ‘john’ has the user id as ‘1’ and lives in ‘111,aaa’ address.

```
insert into ls2user.user1 values ('1','john','111,aaa');
```

```
insert into ls2user.user1 values ('2','allan','222,bbb');
```

```
insert into ls2user.user1 values ('3','tom','333,ccc');
```

```
insert into ls2user.user1 values ('4','tim','444,ddd');
```

```
insert into ls2user.user1 values ('5','mary','555,eee');
```

The following insert statements create the actual mapping between the users with their interests. They populate the table called ‘user_interests’. Here the third expression means that Allan is interested in cars that were manufactured in the year 2000.

```
insert into ls2user.user_interests values ('1','2','4','1');
```

```
insert into ls2user.user_interests values ('1','2','5','5');
```

```
insert into ls2user.user_interests values ('2','1','2','6');
```

```
insert into ls2user.user_interests values ('3','2','4','1');
```

```
insert into ls2user.user_interests values ('4','2','5','2');
```

Screenshot of tables:

This screenshot is taken by issuing a select * from each of the tables as follows

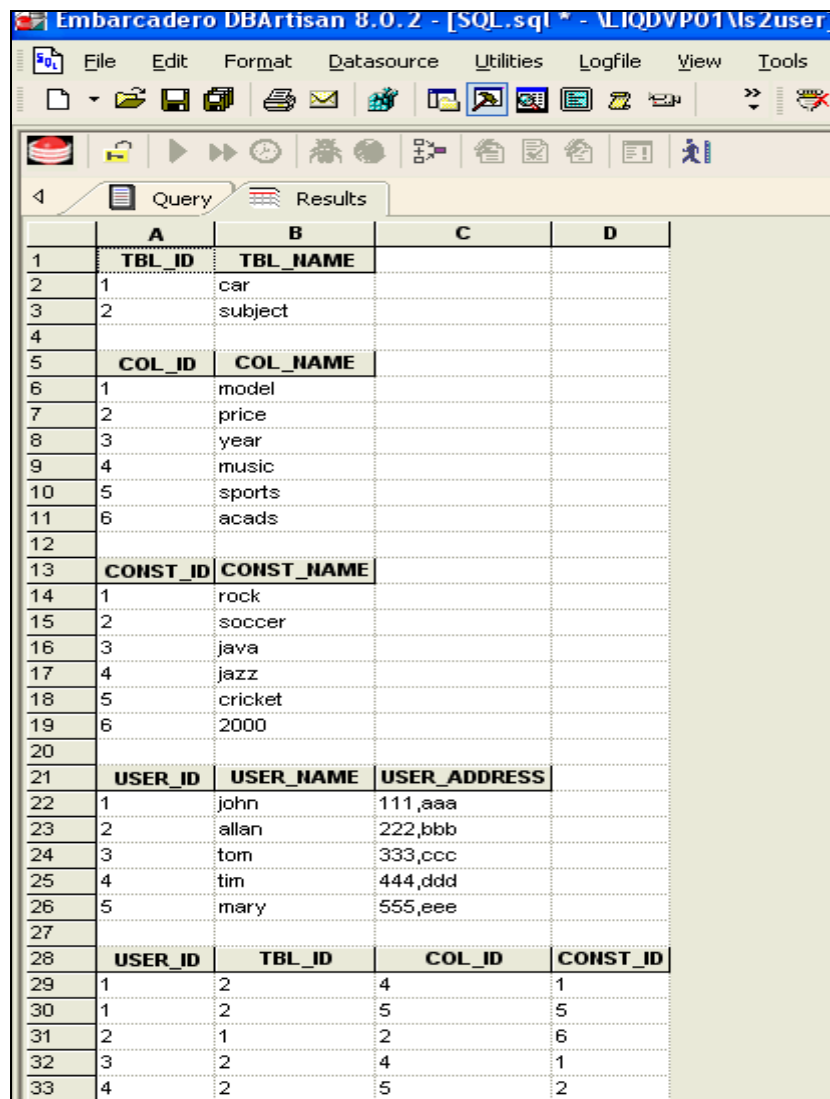
```
select * from ls2user.tbl;
```

```
select * from ls2user.col;
```

```
select * from ls2user.const;
```

```
select * from ls2user.user1;
```

```
select * from ls2user.user_interests;
```



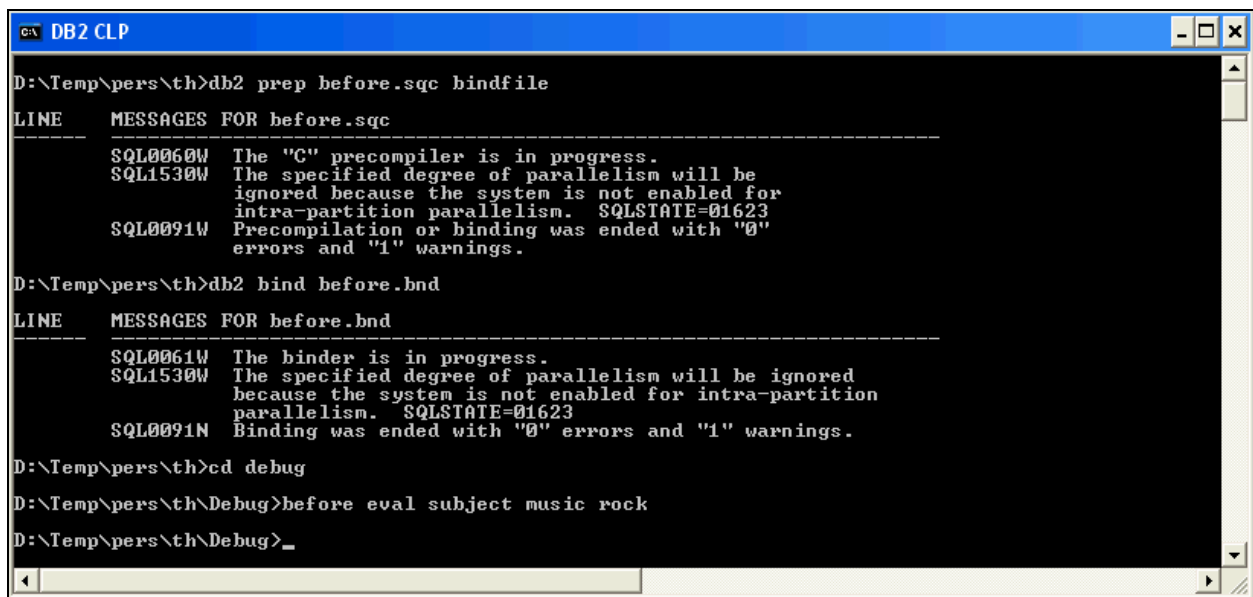
The screenshot displays the Embarcadero DBArtisan 8.0.2 interface. The 'Results' tab is active, showing the output of a query. The results are organized into five distinct sections, each representing a table's data. The first section, 'tbl', has columns TBL_ID and TBL_NAME. The second, 'col', has columns COL_ID and COL_NAME. The third, 'const', has columns CONST_ID and CONST_NAME. The fourth, 'user1', has columns USER_ID, USER_NAME, and USER_ADDRESS. The fifth, 'user_interests', has columns USER_ID, TBL_ID, COL_ID, and CONST_ID. The data is presented in a grid format with row numbers on the left.

	A	B	C	D
1	TBL_ID	TBL_NAME		
2	1	car		
3	2	subject		
4				
5	COL_ID	COL_NAME		
6	1	model		
7	2	price		
8	3	year		
9	4	music		
10	5	sports		
11	6	acads		
12				
13	CONST_ID	CONST_NAME		
14	1	rock		
15	2	soccer		
16	3	java		
17	4	jazz		
18	5	cricket		
19	6	2000		
20				
21	USER_ID	USER_NAME	USER_ADDRESS	
22	1	john	111,aaa	
23	2	allan	222,bbb	
24	3	tom	333,ccc	
25	4	tim	444,ddd	
26	5	mary	555,eee	
27				
28	USER_ID	TBL_ID	COL_ID	CONST_ID
29	1	2	4	1
30	1	2	5	5
31	2	1	2	6
32	3	2	4	1
33	4	2	5	2

Figure 16 Table contents – Before Case

Compilation and Program Execution:

- First step 'prep' creates the C file and the bind file. (sql part -> bind file, c part -> C file are contained in the embedded sqc file)
- Second step 'bind' binds the file to the database.
- The 3rd step is compiling the C program created which is shown in the next screenshot (VC++ to compile)
- The 'exe' file is created in the Debug directory.
- The fourth step is to run the executable 'before' with the arguments.



```
DB2 CLP
D:\Temp\pers\th>db2 prep before.sqc bindfile
LINE  MESSAGES FOR before.sqc
-----
SQL0060W  The "C" precompiler is in progress.
SQL1530W  The specified degree of parallelism will be
          ignored because the system is not enabled for
          intra-partition parallelism.  SQLSTATE=01623
SQL0091W  Precompilation or binding was ended with "0"
          errors and "1" warnings.

D:\Temp\pers\th>db2 bind before.bnd
LINE  MESSAGES FOR before.bnd
-----
SQL0061W  The binder is in progress.
SQL1530W  The specified degree of parallelism will be ignored
          because the system is not enabled for intra-partition
          parallelism.  SQLSTATE=01623
SQL0091N  Binding was ended with "0" errors and "1" warnings.

D:\Temp\pers\th>cd debug
D:\Temp\pers\th\Debug>before eval subject music rock
D:\Temp\pers\th\Debug>_
```

Figure 17 Prepping and executing – Before Case

5.2.2 After Approach – With Expression Datatype

After Approach is a simulation of e-News with expression datatype and is implemented using the mini DBMS. In the after case, the user's interests are modeled in terms of expressions rather than a mere mapping between various tables. An expression would contain the table, column and constant information that was in the before case. Also an operator is present which provides additional information and provides additional functionality in retrieving the data. The expressions are stored in two tables the expression and the predicate table. The user_interests table contains a mapping of expressions with users rather than table, column, constant with users. The link and authentication table remain the same as the before approach and are not implemented in the simulation

5.2.2.1 Data Model

The ER diagram for the after model is shown in the figure 19.

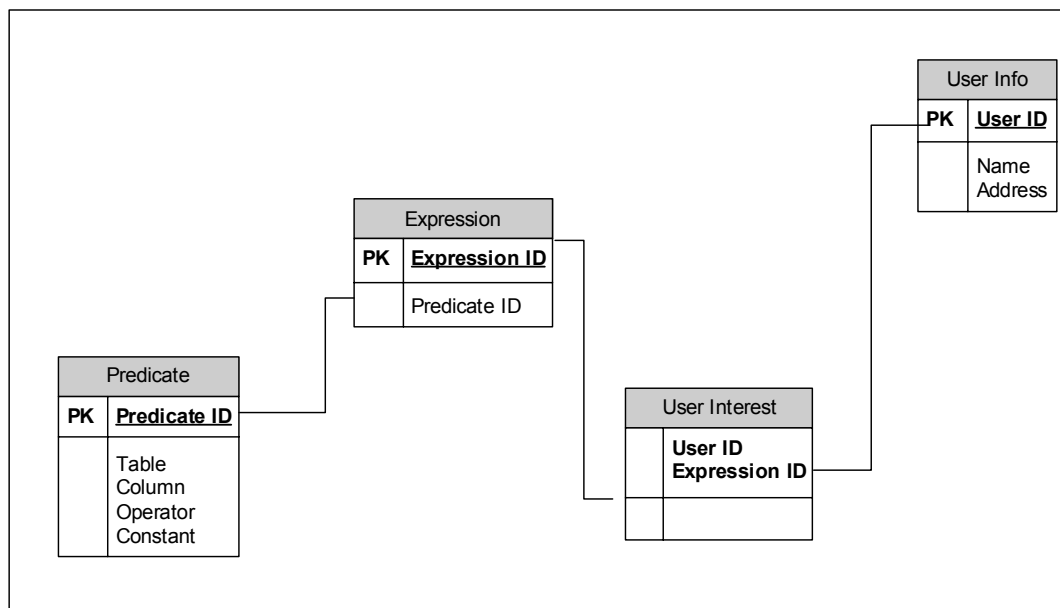


Figure 19 Architecture – After Case

Table Creation and Data Insertion

In the After Approach, we have to add only two tables to the mini DBMS, user and user_interests. The predicate table and the expression table have already been created when a new database is created as explained in the previous chapters. In order to model a user interest, some sample data is entered. Here the user interests entered is the same as the user interests modeled in the before case.

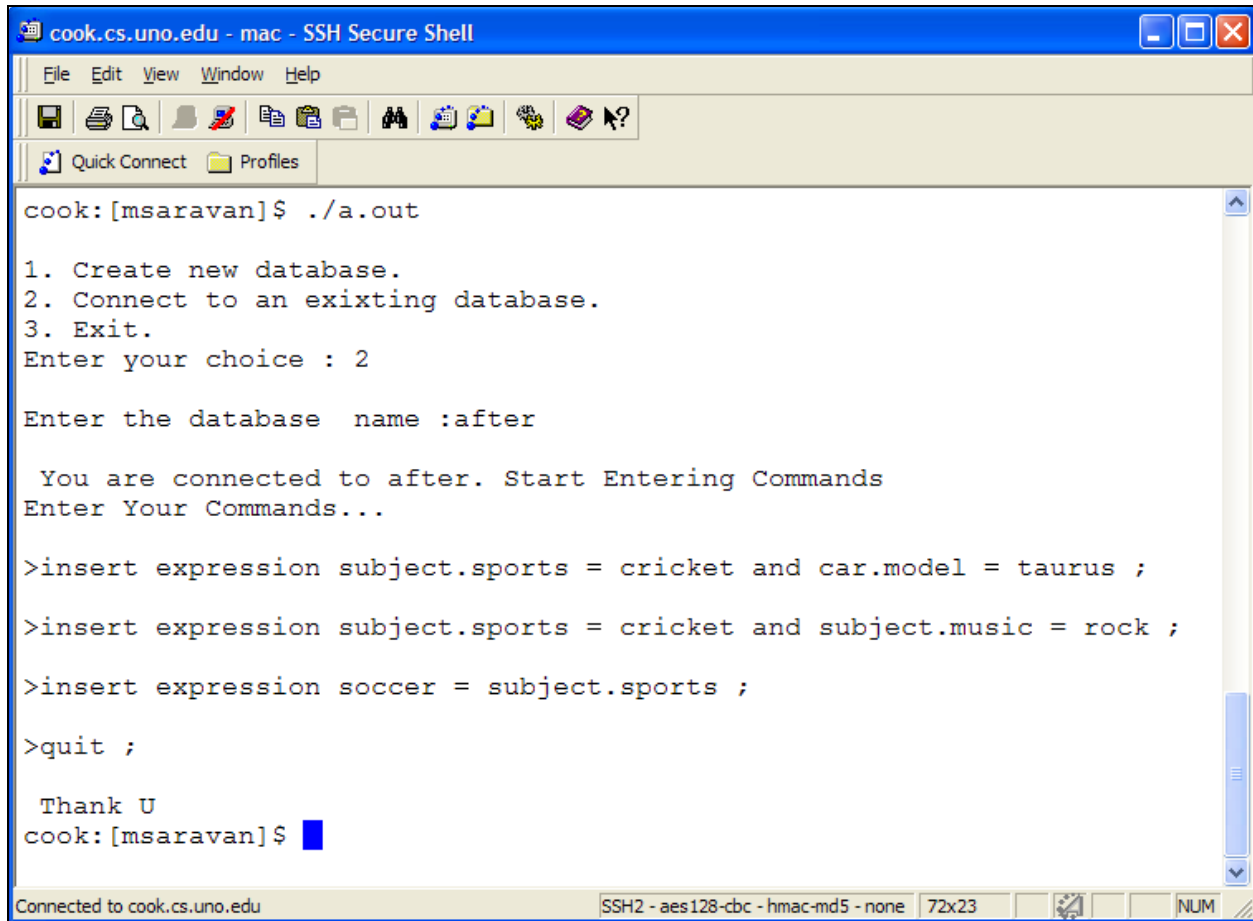
Creating the two tables 'user' and 'user_interests' using the 'Create' statement from the mini DBMS.

```
cook:[msaravan]$ ./a.out
1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 1
Enter the database name :after
You are connected to after. Start Entering Commands
Enter Your Commands...
>create table user ( user_id int , name varchar(20) , address varchar(20) ) ;
table created
>create table user_interests ( user_id int , exp_id int ) ;
table created
>quit ;
Thank U
cook:[msaravan]$
```

Figure 20 Table creation – After Case

The following screenshot shows inserting data into the tables using Insert function of mini DBMS. The insert statements are used to populate Expression and Predicate tables by inserting expressions. It is also used to populate user table as well as user_interest table to create user's profiles.

Inserting data into the tables using Insert function of mini DBMS.

The image is a screenshot of a terminal window titled "cook.cs.uno.edu - mac - SSH Secure Shell". The window has a menu bar with "File", "Edit", "View", "Window", and "Help". Below the menu bar is a toolbar with various icons. The main area of the window shows a command prompt session. The user has entered the command `./a.out`, which has produced a menu with three options: "1. Create new database.", "2. Connect to an existing database.", and "3. Exit.". The user has entered "2". The prompt then asks for a database name, and the user has entered "after". The system responds with "You are connected to after. Start Entering Commands" and "Enter Your Commands...". The user has then entered three SQL insert statements: `>insert expression subject.sports = cricket and car.model = taurus ;`, `>insert expression subject.sports = cricket and subject.music = rock ;`, and `>insert expression soccer = subject.sports ;`. Finally, the user has entered `>quit ;`. The system responds with "Thank U" and the prompt returns to `cook: [msaravan]$`. The status bar at the bottom of the window shows "Connected to cook.cs.uno.edu", "SSH2 - aes128-cbc - hmac-md5 - none", "72x23", and "NUM".

```
cook: [msaravan]$ ./a.out

1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 2

Enter the database name :after

You are connected to after. Start Entering Commands
Enter Your Commands...

>insert expression subject.sports = cricket and car.model = taurus ;
>insert expression subject.sports = cricket and subject.music = rock ;
>insert expression soccer = subject.sports ;
>quit ;

Thank U
cook: [msaravan]$
```

Figure 21 Expression Insertions – After Case

```

1:cook.cs.uno.edu - mac - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles

cook:[msaravan]$ ./a.out

1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 2

Enter the database name :after

You are connected to after. Start Entering Commands
Enter Your Commands...

>insert expression subject.music = rock ;

>insert into user values ( 1 , 'John' , '111,AAA' ) ;

1 row inserted
>insert into user values ( 2 , 'Allan' , '222,BBB' ) ;

1 row inserted
>insert into user values ( 3 , 'Tom' , '333,CCC' ) ;

1 row inserted
>insert into user values ( 4 , 'Tim' , '444,DDD' ) ;

1 row inserted
>insert into user values ( 5 , 'Mary' , '555,EEE' ) ;

1 row inserted
>insert into user_interests values ( 1 , 2 ) ;

1 row inserted
>insert into user_interests values ( 3 , 4 ) ;

1 row inserted
>

```

Figure 22 Profile Insertions – After Case

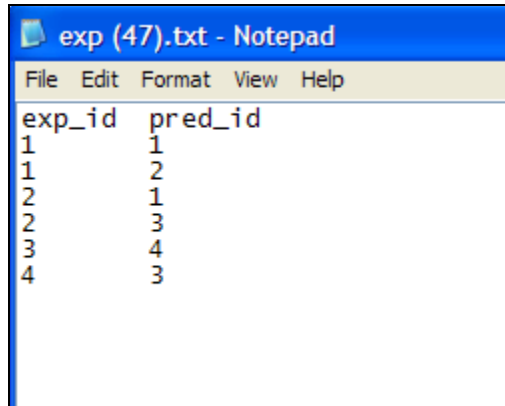
Screenshots of tables:

Predicate table:

pred_id	table	column	operator	constant
1	subject	sports	=	cricket
2	car	model	=	taurus
3	subject	music	=	rock
4	subject	sports	=	soccer

Figure 23 Predicate Table Contents – After Case

Expression table:

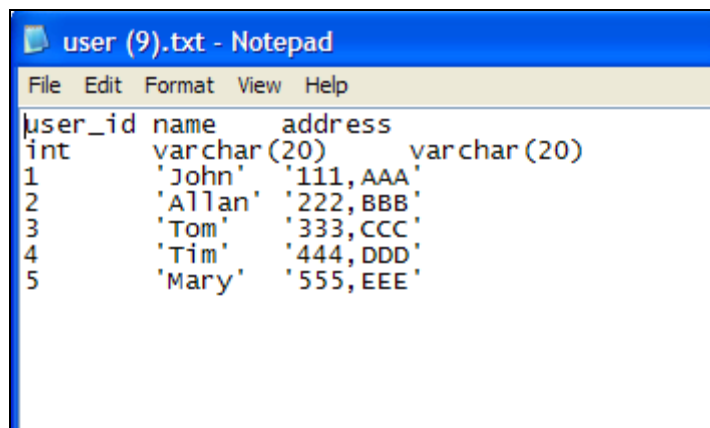


A Notepad window titled "exp (47).txt - Notepad" with a menu bar (File, Edit, Format, View, Help). The text inside shows a table with two columns: "exp_id" and "pred_id".

exp_id	pred_id
1	1
1	2
2	1
2	3
3	4
4	3

Figure 24 *Expression Table Contents – After Case*

User table:

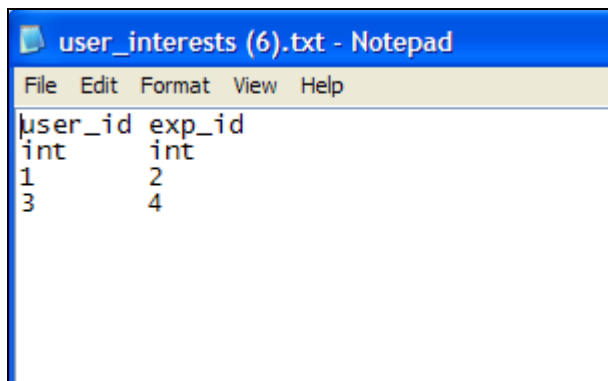


A Notepad window titled "user (9).txt - Notepad" with a menu bar (File, Edit, Format, View, Help). The text inside shows a table with three columns: "user_id", "name", and "address".

user_id	name	address
int	varchar(20)	varchar(20)
1	'John'	'111,AAA'
2	'Allan'	'222,BBB'
3	'Tom'	'333,CCC'
4	'Tim'	'444,DDD'
5	'Mary'	'555,EEE'

Figure 25 *User Table Contents – After Case*

User_interests table:



A Notepad window titled "user_interests (6).txt - Notepad" with a menu bar (File, Edit, Format, View, Help). The text inside shows a table with two columns: "user_id" and "exp_id".

user_id	exp_id
int	int
1	2
3	4

Figure 26 *User Interests Table Contents – After Case*

Execution using EVALUATE operator.

```
cook:[msaravan]$ ./a.out
1. Create new database.
2. Connect to an existing database.
3. Exit.
Enter your choice : 2

Enter the database name :after

You are connected to after. Start Entering Commands
Enter Your Commands...

>evaluate subject.music = rock and subject.sports = cricket ;

'John', '111,AAA'
'Tom', '333,CCC'

CPU time needed to evaluate the previous statement : 0.110000 microsecs

>evaluate subject.music = rock ;

'Tom', '333,CCC'

CPU time needed to evaluate the previous statement : 0.110000 microsecs

>quit ;

Thank U
cook:[msaravan]$
```

Figure 27 Results – After Case

5.3 COMPARISON BETWEEN THE TWO APPROACHES

A comparison between the before and after approaches is done in this section. The comparison is done on two concerns, expressivity and performance.

5.3.1 Expressivity

In terms of expressivity the after approach, which is the approach with Expression data type has advantages over the approach without the Expression data type.

- **Operator**

In the before case, there is no operator that is involved in the predicate. However the only operator that is specified ‘implicitly’ is in the data and that is an ‘=’ operator. In the after case, the predicates stored can have relational operators. For example let us consider the following example where the expression is as follows:

$$\text{Car.Price} < 10000$$

A data item, say Car.Price = 5000 will evaluate to true in the after case. In the before case we cannot express this predicate in the database as it does not support the operator.

- **More than one predicates over one data item**

The before approach doesn’t allow creating conjunctions (i.e., ANDing) when modeling user interest over one data item. E.g., with the before Approach it is possible to express a profile of say ‘John’ who is interested in cars with ‘Model’ = ‘Taurus’ and also in those cars for which ‘Year’ = 2000. However, the before approach doesn’t allow specification of user interest only in those cars for which both ‘Model’ = ‘Taurus’ and ‘Year’ = 2000.

5.3.2 Performance

Different platforms are used for the before and after case. The before case is implemented using DB2 which is full-fledged DBMS, while the after case is implemented on Mini-DBMS, a stripped-down DBMS implemented to support expressions. Differences between these platforms will have a large impact on the performance of the two approaches. Important differences include the following:

- DB2 has indexing support, while Mini-DBMS doesn’t support indexing.

Ability to create indexes will help DB2 perform better.

- DB2 has all the functionality of a DBMS, including query optimization layer, buffer cache, transaction layer, etc. Mini-DBMS was implemented mainly to support expressions and has none of these layers that are needed in a full-fledged DBMS. Absence of all these layers will significantly boost the performance of Mini-DBMS.

These platform differences make a fair experimental performance very difficult.

Below we first give experimental results that compare the performance of the two approaches.

We then discuss these results to interpret the experimental results.

Experiments were carried out to compare the performance of the two approaches based on the speed of evaluation. Sample runs were executed for both before and after cases. The before case with ‘n’ rows in the ‘user_interests’ table was compared to ‘n’ rows in the ‘expression’ table and the results are tabulated in micro seconds.

#	value of ‘n’	Before – microseconds				After – microseconds			
		Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
1	10	0.270	0.254	0.266	0.263333	0.01	0.01	0.01	0.01
2	100	0.288	0.286	0.291	0.288333	0.11	0.11	0.11	0.11
3	1000	0.327	0.373	0.349	0.349667	0.12	0.12	0.12	0.12

Table 9 Performance Comparison – Before and After Case

These statistics can be graphically shown in the following figure.

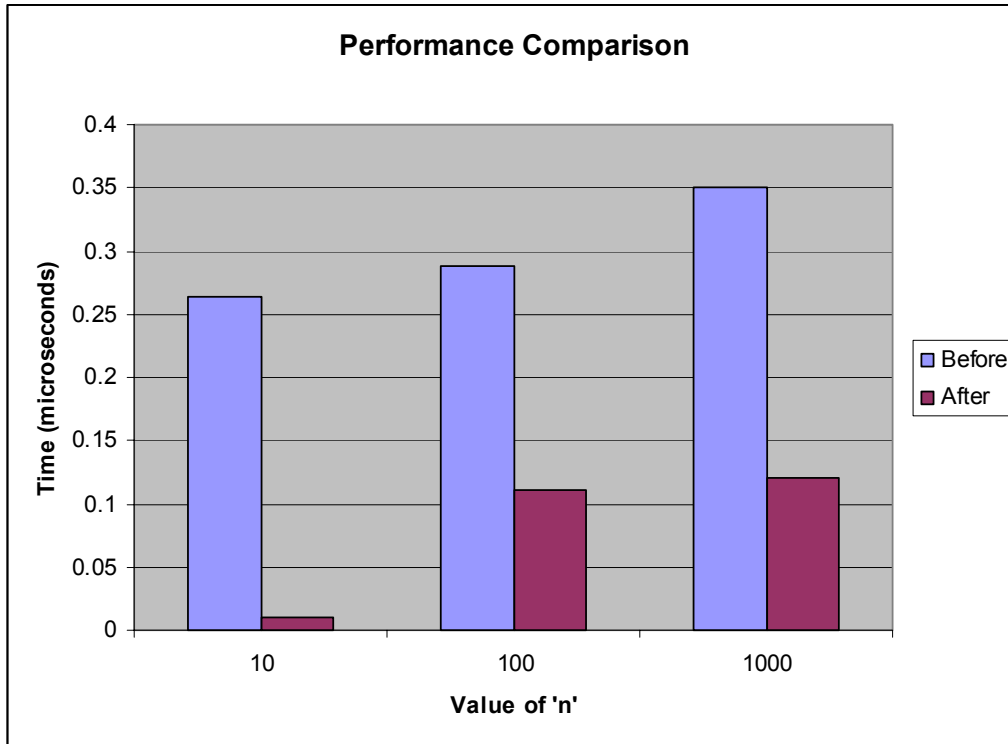


Figure 28 Performance Comparisons – Before and After Case

In the before case the data was entered manually through “Table Insert SQLS” which have already been explained in section 5.2, whereas in the after case data was entered using the script1.c. A sample screenshot is shown for the after case for 100 predicates.

```

1:cook.cs.uno.edu - mac - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles
cook:[msaravan]$ ./a.out

Enter the database : after

1. Generate Predicates and expressions
2. Generate User Profiles
3. Generate News Items
4. Exit

Enter your choice :1

Enter the number of row items to be generated :100

Enter the number of sample values :2

Enter the 2 sample table names : cars bike

Enter the 2 sample column names : year price

Enter the 2 sample constants : 2000 2005

Enter the operator code i.e. 1 for equal to only else 0 : 1

1. Generate Predicates and expressions
2. Generate User Profiles
3. Generate News Items
4. Exit

Enter your choice :4

Connected to cook.cs.uno.edu
SSH2 - aes128-cbc - hmac-md5 - none 80x29 NUM

```

Figure 29 Script File

- We see a considerable increase in performance in the after case. The major cost in database processing is due to I/O. We compare the amount of I/O in the two approaches to understand if the cause of performance improvement is due to different amounts of I/O for the two approaches or due to differences in the underlying platforms.

The SQL used to extract data in the before case is as follows:

```

select user_name, user_address
  from ls2user.user_interests i
    inner join ls2user.user1 u
      on u.user_id = i.user_id
    inner join ls2user.tbl t

```

```

        on i.tbl_id = t.tbl_id

    inner join ls2user.col c

        on i.col_id = c.col_id

    inner join ls2user.const d

        on i.const_id = d.const_id

where

    tbl_name = :tbl

    and col_name = :lcol

    and const_name = :lconst;

```

Consider the experimental run with $n = 100$. In this case, there are 100 rows in ‘user_interest’, 4 rows in ‘table’, 4 rows in ‘column’ and 4 rows in ‘constant.’ Each row in ‘user_interest’ has 4 integers, while each row in ‘table,’ ‘column’ and ‘constant’ has one integer and one string. So total data volume in the before case is approximately

- $100*4 + 4*1 + 4*1 + 4*1 = 412$ integers, and
- $4*1 + 4*1 + 4*1 = 12$ strings.

In the after case for $n = 100$, there were 100 rows in the expression table and 34 distinct expressions. However, there were only 43 rows in the predicate table, since a predicate that appears in multiple expressions is stored only once in the predicate table. Each row in expression table has 2 integers. Each row in the predicate table has ‘table,’ ‘column,’ ‘operator’ and ‘constant’ in addition to a predicate id. Assuming that the size of each ‘operator’ equals an integer, each row in predicate table is composed of 2 integers and 3 strings.

Total data volume in the after case is approximately:

- $100*2 + 43*2 = 286$ integers, and
- $43*3 = 129$ strings.

Comparing the data volumes, we see that the before case requires less I/O. Hence, the performance improvement in the after case is explained by the difference in the underlying platform. Note that the I/O costs for the after case can be improved if appropriate indexes are developed for expression data type. Research into such indices is a major topic for future work for support of expressions in DBMS.

We conclude this section with some notes on the performance of the after case for different values of n , i.e., for different number of rows in the expression table.

- Let p be the number of rows in the predicate table.
- If there are no indexes, n rows in the expression table and p rows in the predicate table will need to be accessed.
- If in a particular set of expressions there is no sharing of predicates among expressions, $p = n$. However, if there is any sharing of predicates, then $p < n$. So in any case $p \leq n$. The greater the sharing of predicates, the smaller p will be relative to n .
- Rows in the predicate table are bigger than rows in the expression table. If sharing of predicates increases with n , p will increase at a much slower rate than the increase of n . Therefore, in such a situation the overall I/O costs will also increase at a much slower than the rate of increase of n .

6. FUTURE DEVELOPMENT

6.1 INDEXING EXPRESSIONS

We have seen that in large number of applications numerous expressions are involved. So providing indexes on the column where the expressions are stored would make the EVALUATE operator faster. Current implementation calculates the time taken for performing the evaluation. If indexes were created on the column where expressions are stored it would be easier to filter the predicates that are evaluated to true and then filter the expressions, which are evaluated to true.

Some research has already been done on indexing expressions [7], with experimental comparisons proving that adding indexes to expressions will increase performance.

Indexes should be created on both predicate table and the expression table which would improve performance of the EVALUATE operator.

6.2 SUPPORTING EXPRESSION AS A NATIVE DATA TYPE

According to [1], in the current work, the column of VARCHAR data type with an Expression constraint is treated as a column of Expression data type. So, the semantics of an Expression instance are lost once it is fetched into a programmatic language like JAVA and C. In order to allow operations on a transient (not stored in a table) version of an expression, native support for the expression data type is required.

Any expression with an invalid variable reference is automatically rejected by the data type check. Additional operators such as an EQUAL operator to check for logical equivalence of two expressions and an IMPLIES operator to determine if one expression implies another expression can be supported by the Expression data type.

6.3 SUPPORTING EVALAUTE AS A NATIVE SQL OPERATOR

Presently, the EVALUATE operator cannot derive the context from the query in which it is used. That is, the data item for which a set of expressions is evaluated should be passed explicitly to the operator as an argument. By supporting EVALUATE operator as a native SQL operator, its functionality can be enhanced to derive the required data items from the current query context. This is beneficial when the data items for which a set of expressions is evaluated are obtained from another table (included in the FROM clause of the same query).

With native SQL support, the EVALUATE operator can also consider alternate execution plans by exploiting any indexes defined on the table storing the data items.

7. CONCLUSION

Many applications require that user's interest in expected data be persistently maintained as conditional expressions and matched against the incoming data. It has been proposed that an expression datatype can be added to Relational Database Management Systems (RDBMS) to support this functionality in an efficient and expressive manner [1].

This thesis focused on supporting such a datatype in RDBMS by allowing expressions to be stored in the database and by implementing a *SQL EVALUATE* operator to evaluate expressions for given data. The syntax and semantics of the proposed expression datatype were described. An implementation of this datatype and an *EVALUATE* operator on a mini-DBMS was explained. An important feature of the implementation is that conditions that are common among different expressions are stored only once. A sample application [12] that needs to maintain user interest and match it to expected data was introduced. This application was used to examine how well the needed functionality is supported by the expression datatype. In terms of expressivity, the expression datatype was found to be much simpler in expressing user interest than other means of representation.

This thesis thus demonstrated that expressions provide a flexible and powerful mechanism for applications that match data to users based on user specified interest. Future work to enhance expression support includes indexing expressions for faster performance, supporting expressions as a native data type with additional logical operators and supporting *EVALUATE* as a native SQL operator.

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VITA

Mahesh Saravanan was born on July 1980 in Tiruchirapalli, India. He completed his high school from Campion Higher Secondary School, Tiruchirapalli. His high school was majoring Mathematics, Sciences and Computer Science. Later in April 2002 he received his bachelor's degree in Computer Science Engineering from Madurai Kamaraj University, India. His bachelor's dissertation was developing a platform independent auto-dialer. He always dreamt to pursue a master's degree in Computer Science and if possible, continue his higher education to pursue a doctoral degree. Later he moved to the United States to pursue his masters. He graduated from University of New Orleans in May 2006 with a Masters degree in Computer Science. He will later, in time look to pursue his doctoral studies.