Dynamic Embedded SQL
Fall, 2018

School of Computer Science
University of Waterloo

Databases CS348
Dynamic SQL

Goal

execute a string as a SQL statement

Problems:

- How do we know a string is a valid statement?
  ⇒ parsing and compilation?

- How do we execute
  ⇒ queries? (where does the answer go?)
  ⇒ updates? (how many rows affected?)

- What if we don’t know anything about the string?

⇒ we develop an “adhoc” application that accepts an SQL statement as an argument and executes it (and prints out answers, if any).
Dynamic SQL: a Roadmap

1. STRING
   - PREPARE
   - EXECUTE IMMEDIATE

2. STATEMENT
   - DECLARE CURSOR
   - EXECUTE
   - DESCRIBE

3. CURSOR

4. TUPLES
   - # ROWS

5. SQLDA
   - # ROWS

6. OPEN/FETCH/CLOSE

7. UNIVERSITY OF WATERLOO
   - Dynamic Embedded SQL

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EXECUTE IMMEDIATE

Execution of **non-parametric** statements **without answer(s)**:

```
EXEC SQL EXECUTE IMMEDIATE :string;
```

where :string is a host variable containing the ASCII representation of the query.

- :string may not return an answer nor contain parameters
- used for constant statements executed only once
  
  ⇒ :string is *compiled* every time we pass through.
We better compile a :string into a stmt...

EXEC SQL PREPARE stmt FROM :string;

stmt can now used for repeatedly executed statements
⇒ avoids recompilation each time we want to execute them

- :string may be a query (and return answers).
- :string may contain parameters.
- stmt is not a host variable but an identifier of the statement used by the preprocessor (careful: can’t be used in recursion!)
Parametric Statements

How do we pass parameters into SQL statements?

- Static embedded SQL
  - host variables as parameters

- Dynamic SQL (strings) and parameters?
  - we can change the string (recompilation)
  - use parameter marker: a "?" in the string

Idea

Values for "?"s are substituted when the statement is to be executed
Simple statement: EXECUTE

How do we execute a prepared “non-query?”

EXEC SQL EXECUTE stmt
    USING :var1 [,....,:vark];

- for statements that don’t return tuples
  ⇒ database modification (INSERT, ...)
  ⇒ transactions (COMMIT)
  ⇒ data definition (CREATE ...)

- values of :var1 ,..., :vark are substituted
  for the parameter markers (in order of appearance)
  ⇒ mismatch causes SQL runtime error!
How do we execute a prepared “query?”

EXEC SQL DECLARE cname CURSOR FOR stmt;
EXEC SQL OPEN  cname
   USING  :var1 [,....,:vark];
EXEC SQL FETCH  cname
   INTO  :out1 [,....,:outn];
EXEC SQL CLOSE  cname;

- for queries we use cursor (like in the static case).
- :var1,...,:vark – supply query parameters.
- :out1,...,:outn – store the resulting tuple.
Unknown number/types of variables??

How do we know/learn what kind of statement a string represents?

We need/use a **dynamic descriptor area**.

The standard says:

- ALLOCATE DESCRIPTOR descr
- GET DESCRIPTOR descr what
- SET DESCRIPTOR descr what

where what is

⇒ get/set the value for COUNT
⇒ get/set value for i-th attribute: VALUE :i assgn

you can use use DATA, TYPE, INDICATOR, ...

- DESCRIBE [INPUT|OUTPUT] stmt INTO descr

In practice we have to use a sqlda descriptor explicitly...
The SQLDA data structure is a SQL description area that defines how a single tuple looks like, where are the data, etc. . .

this is how the DBMS communicates with the application.

It contains (among other things):

- The string ‘SQLDA’ (for identification)
- Number of allocated entries for attributes
- Number of actual attributes; 0 if none
- For every attribute
  - (numeric code of) type
  - length of storage for the attribute
  - pointer to a data variable
  - pointer to a indicator variable
  - name (string and its length)
SQLDA ala DB2

```c
struct sqlname /* AttributeName */ {
    short      length;    /* Name length [1..30] */
    char       data[30];  /* Variable or Column name */
};

struct sqlvar /* Attribute Descriptor */ {
    short      sqltype;   /* Variable data type */
    short      sqllen;    /* Variable data length */
    char       *SQL_POINTER sqldata; /* data buffer */
    short      *SQL_POINTER sqlind;  /* null indicator */
    struct sqlname sqlname;    /* Variable name */
};

struct sqlda /* Main SQLDA */ {
    char       sqldaid[8]; /* Eye catcher = 'SQLDA ' */
    long       sqldabc;    /* SQLDA size in bytes=16+44*SQLN */
    short      sqln;       /* Number of SQLVAR elements */
    short      sqld;       /* Number of used SQLVAR elements */
    struct sqlvar sqlvar[1]; /* first SQLVAR element */
};
```
struct SQLDA {
    long      N;    /* Descriptor size in number of entries */
    char     *V[];  /* Arr of addresses of main variables (data) */
    long     L[];   /* Arr of lengths of data buffers */
    short    T[];   /* Arr of types of buffers */
    short   *I[];   /* Arr of addresses of indicator vars */
    long     F;     /* Number of variables found by DESCRIBE */
    char    *S[];   /* Arr of variable name pointers */
    short   M[];   /* Arr of max lengths of attribute names */
    short   C[];   /* Arr of current lengths of attribute names */
    char   *X[];   /* Arr of indicator name pointers */
    short  Y[];   /* Arr of max lengths of ind. names */
    short  Z[];   /* Arr of cur lengths of ind. names */
};
A prepared statement can be **described**; the description is stored in the **SQLDA** structure.

EXEC SQL DESCRIBE stmt INTO sqlda

The result is:

- the number of result attributes
  → 0: not a query
- for every attribute in the answer
  → its name and length
  → its type
We can use a **SQLDA** descriptor to supply parameters and/or to get the result: **fill in the values and types** and then use the description area as follows.

```
EXEC SQL EXECUTE stmt
    USING DESCRIPTOR :sqlda;

EXEC SQL OPEN cname
    USING DESCRIPTOR :sqlda;

EXEC SQL FETCH cname
    USING DESCRIPTOR :sqlda;

... :sqlda essentially replaces :var1, ..., :vark.
```
**Putting it together:** adhoc.sqc

**adhoc** is an application that executes an SQL statement provided as its argument on the command line.

### Declarations:

```c
#include <stdio.h>
#include <string.h>

EXEC SQL INCLUDE SQLCA;
EXEC SQL INCLUDE SQLDA;

EXEC SQL BEGIN DECLARE SECTION;
  char db[6] = "cs448";
  char sqlstmt[1000];
EXEC SQL END DECLARE SECTION;

struct sqlda *select;
```

(University of Waterloo) Dynamic Embedded SQL
Start up and **prepare** the statement:

```c
int main(int argc, char *argv[]) {
    int i, isnull; short type;
    printf("Sample C program : ADHOC interactive SQL\n");

    EXEC SQL WHENEVER SQLERROR  GO TO error;

    EXEC SQL CONNECT TO :db;
    printf("Connected to DB2\n");

    strncpy(sqlstmt,argv[1],1000);
    printf("Processing <%s>\n",sqlstmt);

    EXEC SQL PREPARE stmt FROM :sqlstmt;

    init_da(&select,1);

    EXEC SQL DESCRIBE stmt INTO :*select;
    i= select->sqld;
}```
if (i>0) {
    printf("... looks like a query\n");

    /* new SQLDA to hold enough descriptors for answer */
    init_da(&select,i);

    /* get the names, types, etc... */
    EXEC SQL DESCRIBE stmt INTO :*select;

    printf("Number of select variables <%d>\n",select->sqld);
    for (i=0; i<select->sqld; i++) {
        printf(" variable %d <%. *s (%d%s %[d])>\n", 
            i,
            select->sqlvar[i].sqlname.length,
            select->sqlvar[i].sqlname.data,
            select->sqlvar[i].sqltype,
            ( (select->sqlvar[i].sqltype&1)==1 ? 
                "": " not null" ),
            select->sqlvar[i].sqlllen);
    }
    printf("\n");
...more processing for queries: prepare buffers and print a header.

```c
for (i=0; i<select->sqld; i++) {
    select->sqlvar[i].sqldata = malloc(select->sqlvar[i].sqlllen);
    select->sqlvar[i].sqlind = malloc(sizeof(short));
    *select->sqlvar[i].sqlind = 0;
}

for (i=0; i<select->sqld; i++)
    printf("%-.*s ", select->sqlvar[i].sqlllen,
            select->sqlvar[i].sqlname.length,
            select->sqlvar[i].sqlname.data);

printf("\n");
```
adhoc.sqc (cont.)

...more processing for queries: fetch and print answers.

```sql
EXEC SQL DECLARE cstmt CURSOR FOR stmt;
EXEC SQL OPEN cstmt;
EXEC SQL WHENEVER NOT FOUND GO TO end;
for (;;) {
    EXEC SQL FETCH cstmt USING DESCRIPTOR :*select;
    for (i=0; i<select->sqld; i++)
        if ( *(select->sqlvar[i].sqlind) < 0 )
            print_var("NULL", select->sqlvar[i].sqltype,
            select->sqlvar[i].sqlname.length,
            select->sqlvar[i].sqllen);
        else
            print_var(select->sqlvar[i].sqldata,
            select->sqlvar[i].sqltype,
            select->sqlvar[i].sqlname.length,
            select->sqlvar[i].sqllen);
    printf("\n");
}
end: printf("\n");
```
...otherwise its a simple statement: just execute it.

    } else {
      printf(" ... looks like an update\n");

      EXEC SQL EXECUTE stmt;
    };

    /* and get out of here */
    EXEC SQL COMMIT;
    EXEC SQL CONNECT reset;
    exit(0);

error:
    check_error("My error", &sqlca);
    EXEC SQL WHENEVER SQLERROR CONTINUE;

    EXEC SQL ROLLBACK;
    EXEC SQL CONNECT reset;
    exit(1);
}
**Example**

```
bash-2.05b$ ./adhoc "select * from author"
Sample C program : ADHOC interactive SQL
Connected to DB2
Processing <select * from author>
    ... looks like a query
Number of select variables <3>
    variable 0 <AID (496 not null [4])>
    variable 1 <NAME (453 [22])>
    variable 2 <URL (453 [42])>

<table>
<thead>
<tr>
<th>AID</th>
<th>NAME</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Toman, David</td>
<td><a href="http://db.uwaterloo.ca/~david">http://db.uwaterloo.ca/~david</a></td>
</tr>
<tr>
<td>2</td>
<td>Chomicki, Jan</td>
<td><a href="http://cs.buffalo.edu/~chomick">http://cs.buffalo.edu/~chomick</a></td>
</tr>
<tr>
<td>3</td>
<td>Saake, Gunter</td>
<td>NULL</td>
</tr>
</tbody>
</table>
```
Summary

- given a string:
  - unknown: DESCRIBE
  - simple statement used once: EXECUTE IMMEDIATE
  - otherwise: PREPARE

- given a statement handle (using PREPARE):
  - simple statement: EXECUTE
  - query: DECLARE CURSOR

and then process as a ordinary cursor

Remember to supply correct host variables/sqlda for all parameter and answer tuples!