EMBEDDED SQL

Part 2: Dynamic Statements

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Dynamic SQL

GOAL: to *execute* a string as a SQL statement.

Problems:

- How do we know a string is a valid statement?

  $\Rightarrow$ parsing and compilation?

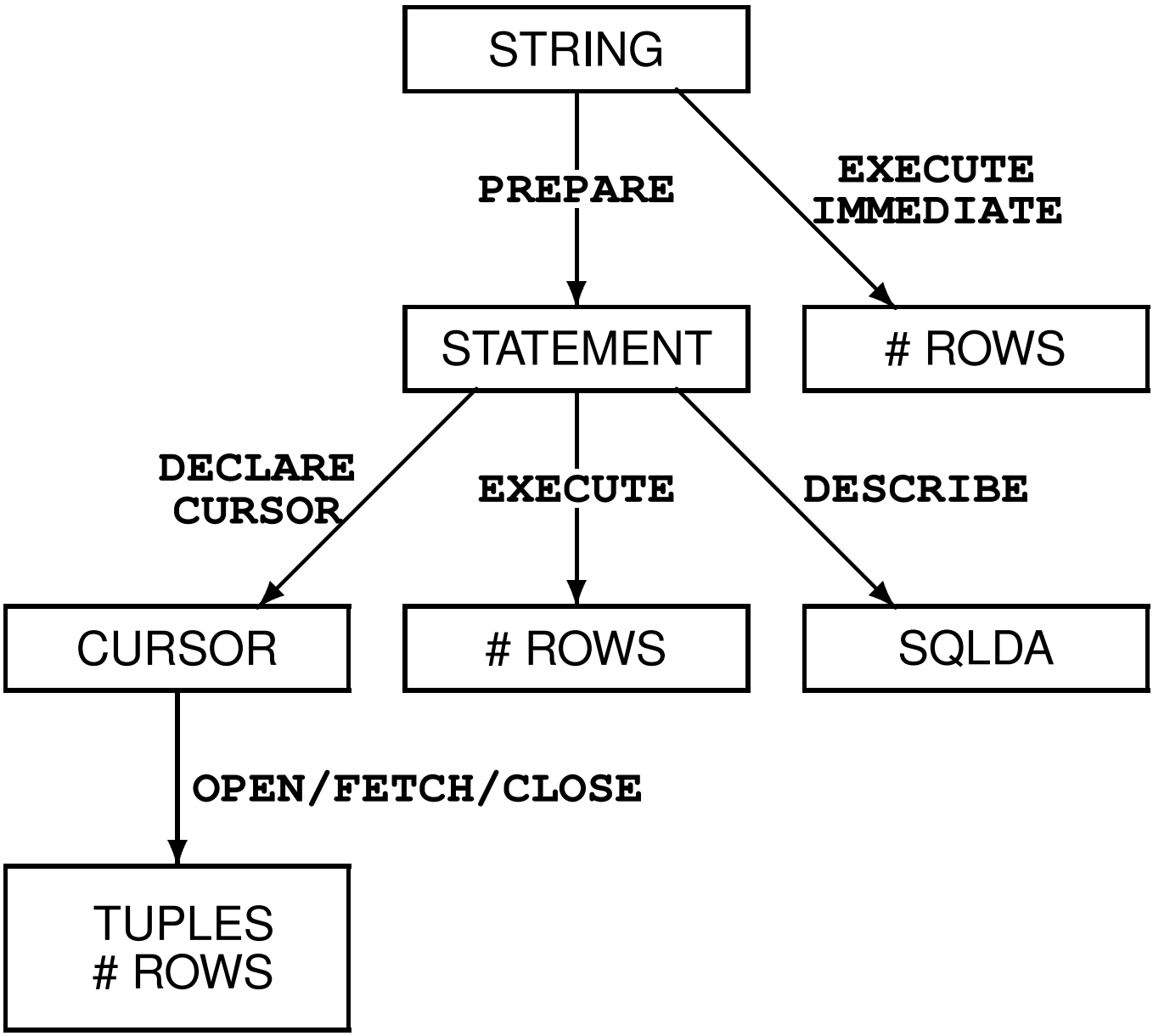
- How do we execute

  $\Rightarrow$ queries? (where does the answer go?)
  $\Rightarrow$ updates? (how many rows affected?)

- What is 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 the answer, if any).

Dynamic SQL: a Roadmap



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 (see later).
- used for constant statements executed only once

  $\Rightarrow$ `:string` is *compiled* every time we pass through.

PREPARE

Often we better **compile** a `:string` into a `stmt`:

```
EXEC SQL PREPARE stmt FROM :string;
```

- 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

- Static embedded SQL

  $\Rightarrow$ host variables as parameters
  $\Rightarrow$ mostly used in **`WHERE`** clause(s)

- Dynamic SQL (strings) and **parameters**?

  $\Rightarrow$ we can change the string (recompilation)
  $\Rightarrow$ use **parameter marker**: **`"?"`** in the string

  Values for **`"?"`**s are substituted
  when the statement is to be executed

Simple statement: EXECUTE

```
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 parameters (in order of appearance)

  ⇒ mismatch causes SQL runtime error!

- **sqlca.sqlerrd[2]** contains the number of affected tuples (for updates)

Query with many answers: CURSOR

```
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.
- **`sqlca.sqlerrd[2]`** the number of retrieved tuples.

Unknown number/types of variables??

We need a dynamic **descriptor area**.

The standard says:

- **`ALLOCATE DESCRIPTOR descr`**
- **`GET DESCRIPTOR descr what`**
  `SET DESCRIPTOR descr what`

  where **`what`** is
  $\Rightarrow$ get/set the value for **`COUNT`**
  $\Rightarrow$ 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...

SQLDA: a description of tuples

`sqlda` is a SQL **description area** that defines a single tuple (this is how the DBMS communicates with the application in the end).

$\Rightarrow$ 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
  1. (numeric code of) type
  2. length of storage for the attribute
  3. pointer to a data variable
  4. pointer to a indicator variable
  5. name (string and its length)

SQLDA (cont.)

A modern version (DB2):

```
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 indiciator     */
  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        */
};
```

SQLDA (cont.)

An archaic version (ORACLE):

```
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          */
};
```

DESCRIBE

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
  - ⇒ negative: SQLDA to small [ORACLE]
- for every attribute in the answer
  - ⇒ its name and length
  - ⇒ its type

SQLDA and parameter passing

We can use a **SQLDA** descriptor to supply parameters and/or to get the result.

You **fill in the values and types** and then use the description area in the following statements:

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

EXEC SQL OPEN cname
         USING DESCRIPTOR :sqlda;

EXEC SQL FETCH cname
         USING DESCRIPTOR :sqlda;
```

. . . essentially in places we used `: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:

```
#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;
```

adhoc.sqc (cont.)

Start up and **prepare** the statement:

```
int main(int argc, char *argv[]) {
   int i, isnull; short type;

   printf("Sample C program : ADHOC interactive SQL\n");

   /* bail out on error */
   EXEC SQL WHENEVER SQLERROR  GO TO error;

   /* connect to the database */
   EXEC SQL CONNECT TO :db;
   printf("Connected to DB2\n");

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

   /* compile the sql statement */
   EXEC SQL PREPARE stmt FROM :sqlstmt;

   init_da(&select,1);

   /* now we find out what it is */
   EXEC SQL DESCRIBE stmt INTO :*select;

   i= select->sqld;
```

adhoc.sqc (cont.)

. . . its a query:

```
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].sqllen);
  }
  printf("\n");
```

adhoc.sqc (cont.)

. . . more processing for queries:

```
  for (i=0; i<select->sqld; i++ ) {
    select->sqlvar[i].sqldata=malloc(select->sqlvar[i].sqllen);
    select->sqlvar[i].sqlind=malloc(sizeof(short));
    *select->sqlvar[i].sqlind = 0;
  };
  EXEC SQL DECLARE cstmt CURSOR FOR stmt;
  EXEC SQL OPEN cstmt;
  EXEC SQL WHENEVER NOT FOUND GO TO end;
  for (i=0; i<select->sqld; i++ )
    printf("%-*.*s ",select->sqlvar[i].sqllen,
                     select->sqlvar[i].sqlname.length,
                     select->sqlvar[i].sqlname.data);
  printf("\n");
  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");
```

adhoc.sqc (cont.)

. . . otherwise its a simple statement:

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

      EXEC SQL EXECUTE stmt;
    };
    printf("Rows processed: %d\n",sqlca.sqlerrd[2]);

    /* 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$ ./adhoc "select * from author"
Sample C program : ADHOC interactive SQL
Password:
Connected to ORACLE
Processing <select * from author>
      ... looks like a query
Number of select variables <3>
  variable 0 <AID (2 not null [14])>
  variable 1 <NAME (96 [22])>
  variable 2 <URL (96 [42])>

AID NAME                      URL
  1 Toman, David              http://brics.dk/~david
  2 Chomicki, Jan             http://cs.monmouth.edu/~c
  3 Saake, Gunter             **null**
  4 Niwinski, Damian          http://zls.mimuw.edu.pl/~
  5 Snodgrass, Richard T.     http://www.cs.arizona.edu

Rows processed: 5
```

Summary

- given a string:
  - ⇒ simple statement used once: **`EXECUTE IMMEDIATE`**
  - ⇒ otherwise: **`PREPARE`**
- given a statement handle (using **`PREPARE`**):
  - ⇒ simple statement: **`EXECUTE`**
  - ⇒ query: **`DECLARE CURSOR`**
    and process as a ordinary cursor
  - ⇒ unknown: **`DESCRIBE`**

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