61A Lecture 33

Wednesday, November 19

Announcements

- Project 4 due Friday 11/21 @ 11:59pm
  - Early submission point #3: Submit by Thursday 11/20 @ 11:59pm
- Homework 9 (6 pts) due Wednesday 11/26 @ 11:59pm
- Guest in live lecture, TA Soumya Basu, on Monday 11/24 (videos still by John)
- No lecture on Wednesday 11/26 (turkey)

Numerical Expressions

Numerical Expressions

Expressions can contain function calls and arithmetic operators

```
          [expression] as [name], [expression] as [name], ...
        ╭──────────────────────────────────────────────────────╮
select [columns] from [table] where [expression] order by [expression];
```

Combine values: +, -, *, /, %, and, or

Transform values: abs, round, not, -

Compare values: <, <=, >, >=, <>, !=, =

(Demo)

String Expressions

String Expressions

String values can be combined to form longer strings

```
sqlite> select "hello," || " world";
hello, world
```

Basic string manipulation is built into SQL, but differs from Python

```
sqlite> create table phrase as select "hello, world" as s;
sqlite> select substr(s, 4, 2) || substr(s, instr(s, " ")+1, 1) from phrase;
low
```

Strings can be used to represent structured values, but doing so is rarely a good idea

```
sqlite> create table lists as select "one" as car, "two,three,four" as cdr;
sqlite> select substr(cdr, 1, instr(cdr, ",")-1) as cadr from lists;
two
```

(Demo)

SQL Execution

Useful Python Features

The namedtuple function returns a new sub-class of tuple

```
>>> from collections import namedtuple
>>> City = namedtuple("City", ["latitude", "longitude", "name"])
>>> cities = [City(38, 122, "Berkeley"),
              City(42,  71, "Cambridge"),
              City(43,  93, "Minneapolis")]
>>> [city.latitude for city in cities]
[38, 42, 43]
```

Attribute names are accessible as the _fields attribute of an instance of City

```
>>> print(cities[0])
City(latitude=38, longitude=122, name='Berkeley')
>>> print(cities[0]._fields)
('latitude', 'longitude', 'name')
```

The eval function can take a dictionary of name-value bindings as a second argument

```
>>> eval("latitude + 3")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 1, in <module>
NameError: name 'latitude' is not defined
>>> eval("latitude + 3", {"latitude": 38})
41
```

A Select Statement Filters, Sorts, and Maps Rows

One correct (but not always efficient) implementation of `select` uses sequence operations

```
sqlite> select name, 60*abs(latitude-38) as distance from cities where name != "Berkeley";
Miami|720
San Diego|300
Cambridge|240
Minneapolis|420
North Pole|3120
```

```
>>> Distance = namedtuple("Row", ["name", "distance"])
>>> def columns(city):
        latitude, longitude, name = city
        return Distance(name, 60*abs(latitude-38))
>>> def condition(city):
        latitude, longitude, name = city
        return name != "Berkeley"
>>> for row in map(columns, filter(condition, cities)):
        print(row)
Row(name='Miami', distance=720)
...
```

Names from column description

Expressions from column description

Interpreting Select Statements

A Select Class

The SQL parser creates an instance of the Select class for each select statement

```
>>> class Select:
        """select [columns] from [tables] where [condition]."""
        def __init__(self, columns, tables, condition):
            self.columns = columns
            self.tables = tables
            self.condition = condition
            self.make_row = create_make_row(self.columns)
        def execute(self, env):
            """Join, filter, and map rows from tables to columns."""
            from_rows = join(self.tables, env)
            filtered_rows = filter(self.filter_fn, from_rows)
            return map(self.make_row, filtered_rows)
        def filter_fn(self, row):
            if self.condition:
                return eval(self.condition, row)
            else:
                return True
```

Simplified version of http://composingprograms.com/examples/sql/sql_exec.py

Creating Row Classes Dynamically

Each select statement creates a table with new columns, represented by a new class

```
>>> def create_make_row(description):
        """Return a function from an input environment (dict) to an output row.

        description -- a comma-separated list of [expression] as [column name]
        """
        columns = description.split(", ")
        expressions, names = [], []
        for column in columns:
            if " as " in column:
                expression, name = column.split(" as ")
            else:
                expression, name = column, column
            expressions.append(expression)
            names.append(name)
        row = namedtuple("Row", names)
        return lambda env: row(*[eval(e, env) for e in expressions])
```

Joining Rows

Joining creates a dictionary with all names and aliases for each combination of rows

```
>>> from itertools import product
>>> def join(tables, env):
        """Return an iterator over dictionaries from names to values in a row."""
        names = tables.split(", ")
        joined_rows = product(*[env[name] for name in names])
        return map(lambda rows: make_env(rows, names), joined_rows)
>>> def make_env(rows, names):
        """Create an environment of names bound to values."""
        env = dict(zip(names, rows))
        for row in rows:
            for name in row._fields:
                env[name] = getattr(row, name)
        return env
```

(Demo)

SQL Interpreter Examples

Interpreting SQL Using Python

Fill in the blanks in this interactive Python session that interprets these SQL statements

```
create table cities as
  select 38 as lat, 122 as lon, "Berkeley" as name union
  select 42,         71,        "Cambridge"        union
  select 45,         93,        "Minneapolis";
select 60*(lat-38) as north from cities where name != "Berkeley";
```

```
>>> City = namedtuple("City", ["lat", "lon", "name"])
>>> cities = [City(38, 122, "Berkeley"), City(42,  71, "Cambridge"), City(43,  93, "Minneapolis")]

>>> s = Select(_____________________, _____________, _____________________________)

>>> for row in s.execute(_____________________________________________________________):
...     print(row)
...
Row(north=240)
Row(north=300)
```

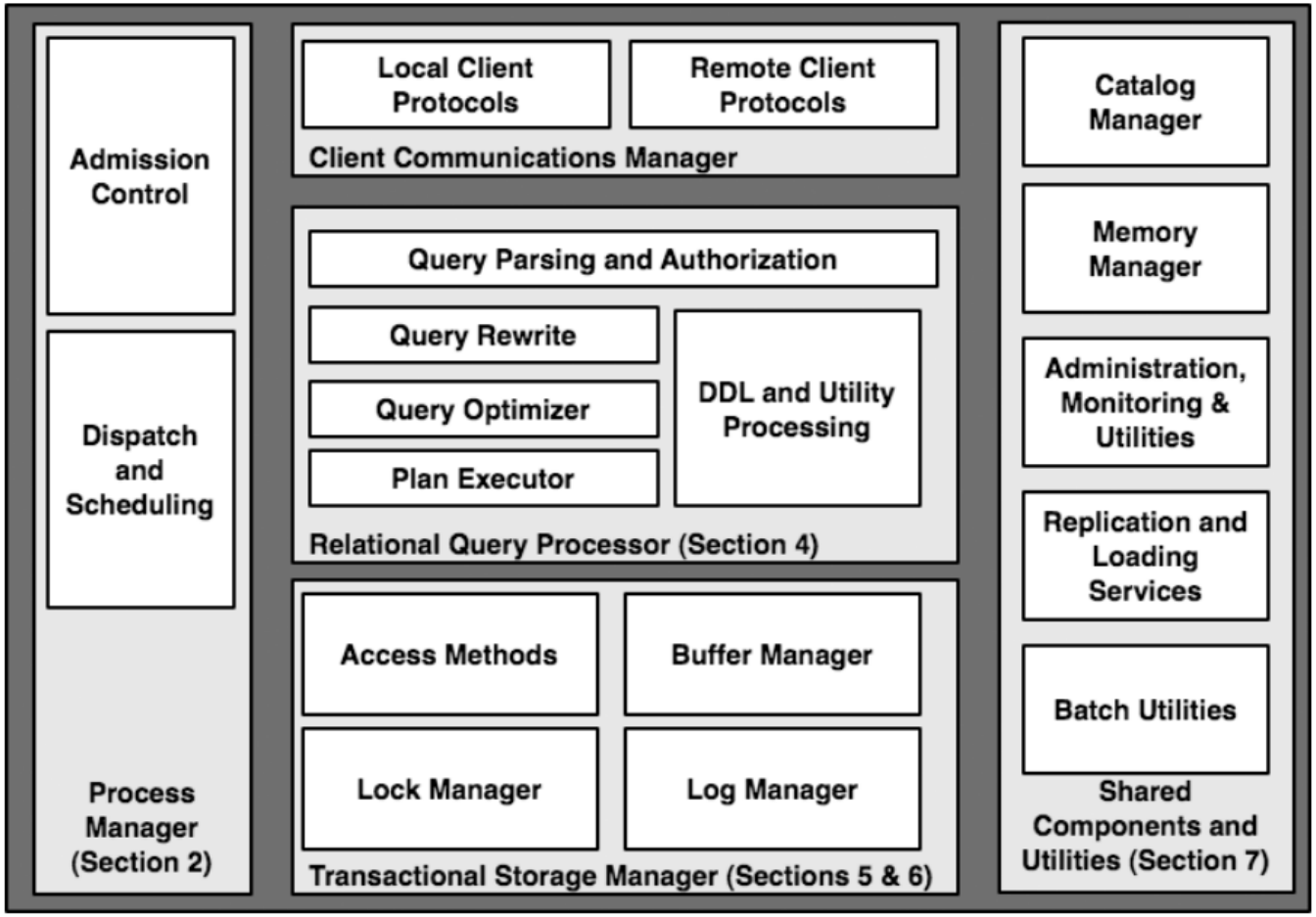
{"cities": cities}

How many times is `eval` called during this call to `s.execute`? (Demo)

```
>>> class Select:
        """select [columns] from [tables] where [condition]."""
        def __init__(self, columns, tables, condition):
            ...
        def execute(self, env):
            ...
```

Database Management Systems

Database Management System Architecture



Architecture of a Database System by Hellerstein, Stonebreaker, and Hamilton

Query Planning

The manner in which tables are filtered, sorted, and joined affects execution time

Select the parents of curly-furred dogs:

```
select parent from parents, dogs
                where child = name and fur = "curly";
```

Join all rows of parents to all rows of dogs, filter by child = name and fur = "curly"

Join only rows of parents and dogs where child = name, filter by fur = "curly"

Filter dogs by fur = "curly", join result with all rows of parents, filter by child = name

Filter dogs by fur = "curly", join only rows of result and parents where child = name