1 Introduction

SQL is an example of a declarative programming language. Statements do not describe computations directly, but instead describe the desired result of some computation. It is the role of the query interpreter of the database system to plan and perform a computational process to produce such a result.

In SQL, data is organized into tables. A table has a fixed number of named columns. A row of the table represents a single data record and has one value for each column. For example, we have a table named records that stores information about the employees at a small company\(^1\). Each of the eight rows represents an employee.

<table>
<thead>
<tr>
<th>Name</th>
<th>Division</th>
<th>records</th>
<th>Salary</th>
<th>Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ben Bitdiddle</td>
<td>Computer</td>
<td>Wizard</td>
<td>60000</td>
<td>Oliver Warbucks</td>
</tr>
<tr>
<td>Alyssa P Hacker</td>
<td>Computer</td>
<td>Programmer</td>
<td>40000</td>
<td>Ben Bitdiddle</td>
</tr>
<tr>
<td>Cy D Fect</td>
<td>Computer</td>
<td>Programmer</td>
<td>35000</td>
<td>Ben Bitdiddle</td>
</tr>
<tr>
<td>Lem E Tweakit</td>
<td>Computer</td>
<td>Technician</td>
<td>25000</td>
<td>Ben Bitdiddle</td>
</tr>
<tr>
<td>Louis Reasoner</td>
<td>Computer</td>
<td>Programmer Trainee</td>
<td>30000</td>
<td>Alyssa P Hacker</td>
</tr>
<tr>
<td>Oliver Warbucks</td>
<td>Administration</td>
<td>Big Wheel</td>
<td>150000</td>
<td>Oliver Warbucks</td>
</tr>
<tr>
<td>Eben Scrooge</td>
<td>Accounting</td>
<td>Chief Accountant</td>
<td>75000</td>
<td>Oliver Warbucks</td>
</tr>
<tr>
<td>Robert Cratchet</td>
<td>Accounting</td>
<td>Scrivener</td>
<td>18000</td>
<td>Eben Scrooge</td>
</tr>
</tbody>
</table>

For this discussion, you can test out your code at sql.cs61a.org. the records table should already be loaded in.

Video walkthrough

2 Creating Tables

We can use a SELECT statement to create tables. The following statement creates a table with a single row, with columns named “first” and “last”:

```
sqlite> SELECT "Ben" AS first, "Bitdiddle" AS last;
Ben|Bitdiddle
```

Given two tables with the same number of columns, we can combine their rows into a larger table with UNION:

```
sqlite> SELECT "Ben" AS first, "Bitdiddle" AS last UNION
   ...> SELECT "Louis", "Reasoner";
Ben|Bitdiddle
Louis|Reasoner
```

\(^1\)Example adapted from Structure and Interpretation of Computer Programs
To save a table, use `CREATE TABLE` and a name. Here we’re going to create the table of employees from the previous section and assign it to the name `records`:

```sql
sqlite> CREATE TABLE records AS
...> SELECT "Ben Bitdiddle" AS name, "Computer" AS division,
...> "Wizard" AS title, 60000 AS salary,
...> "Oliver Warbucks" AS supervisor UNION
...> SELECT "Alyssa P Hacker", "Computer",
...> "Programmer", 40000, "Ben Bitdiddle" UNION ... ;
```

We can SELECT specific values from an existing table using a `FROM` clause. This query creates a table with two columns, with a row for each row in the `records` table:

```sql
sqlite> SELECT name, division FROM records;
Alyssa P Hacker|Computer
Ben Bitdiddle|Computer
Cy D Fect|Computer
Eben Scrooge|Accounting
Lem E Tweakit|Computer
Louis Reasoner|Computer
Oliver Warbucks|Administration
Robert Cratchet|Accounting
```

The special syntax `SELECT *` will select all columns from a table. It’s an easy way to print the contents of a table.

```sql
sqlite> SELECT * FROM records;
Alyssa P Hacker|Computer|Programmer|40000|Ben Bitdiddle
Ben Bitdiddle|Computer|Wizard|60000|Oliver Warbucks
Cy D Fect|Computer|Programmer|35000|Ben Bitdiddle
Eben Scrooge|Accounting|Chief Accountant|75000|Oliver Warbucks
Lem E Tweakit|Computer|Technician|25000|Ben Bitdiddle
Louis Reasoner|Computer|Programmer Trainee|30000|Alyssa P Hacker
Oliver Warbucks|Administration|Big Wheel|150000|Oliver Warbucks
Robert Cratchet|Accounting|Scrivener|18000|Eben Scrooge
```

We can choose which columns to show in the first part of the `SELECT`, we can filter out rows using a `WHERE` clause, and sort the resulting rows with an `ORDER BY` clause. In general the syntax is:

```
SELECT [columns] FROM [tables]
    WHERE [condition] ORDER BY [criteria];
```

For instance, the following statement lists all information about employees with the “Programmer” title.

```sql
sqlite> SELECT * FROM records WHERE title = "Programmer";
Alyssa P Hacker|Computer|Programmer|40000|Ben Bitdiddle
Cy D Fect|Computer|Programmer|35000|Ben Bitdiddle
```

The following statement lists the names and salaries of each employee under the accounting division, sorted in descending order by their salaries.

```
Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
```
sqlite> SELECT name, salary FROM records
...> WHERE division = "Accounting" ORDER BY -salary;
Eben Scrooge|75000
Robert Cratchet|18000

Note that all valid SQL statements must be terminated by a semicolon (;). Additionally, you can split up your statement over many lines and add as much whitespace as you want, much like Scheme. But keep in mind that having consistent indentation and line breaking does make your code a lot more readable to others (and your future self)!

Questions

Our tables:

<table>
<thead>
<tr>
<th>Name</th>
<th>Division</th>
<th>Title</th>
<th>Salary</th>
<th>Supervisor</th>
</tr>
</thead>
</table>

2.1 Write a query that outputs the names of employees that Oliver Warbucks directly supervises.

SELECT name FROM records WHERE supervisor = "Oliver Warbucks";

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2.2 Write a query that outputs all information about employees that supervise themselves.

SELECT * FROM records WHERE name = supervisor;

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2.3 Write a query that outputs the names of all employees with salary greater than 50,000 in alphabetical order.

SELECT name FROM records WHERE salary > 50000 ORDER BY name;

Video walkthrough

3 Joins

Suppose we have another table meetings which records the divisional meetings.

<table>
<thead>
<tr>
<th>Division</th>
<th>Day</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting</td>
<td>Monday</td>
<td>9am</td>
</tr>
<tr>
<td>Computer</td>
<td>Wednesday</td>
<td>4pm</td>
</tr>
<tr>
<td>Administration</td>
<td>Monday</td>
<td>11am</td>
</tr>
<tr>
<td>Administration</td>
<td>Wednesday</td>
<td>4pm</td>
</tr>
</tbody>
</table>

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Data are combined by joining multiple tables together into one, a fundamental operation in database systems. There are many methods of joining, all closely related, but we will focus on just one method (the inner join) in this class.

When tables are joined, the resulting table contains a new row for each combination of rows in the input tables. If two tables are joined and the left table has $m$ rows and the right table has $n$ rows, then the joined table will have $mn$ rows. Joins are expressed in SQL by separating table names by commas in the FROM clause of a SELECT statement.

```sql
sqlite> SELECT name, day FROM records, meetings;
Ben Bitdiddle | Monday
Ben Bitdiddle | Wednesday
...
Alyssa P Hacker | Monday
...
```

Tables may have overlapping column names, and so we need a method for disambiguating column names by table. A table may also be joined with itself, and so we need a method for disambiguating tables. To do so, SQL allows us to give aliases to tables within a FROM clause using the keyword AS and to refer to a column within a particular table using a dot expression. In the example below we find the name and title of Louis Reasoner’s supervisor.

```sql
sqlite> SELECT b.name, b.title FROM records AS a, records AS b
...> WHERE a.name = "Louis Reasoner" AND
...> a.supervisor = b.name;
Alyssa P Hacker | Programmer
```

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Questions

Our tables:

```
  records: Name Division Title Salary Supervisor
  meetings: Division Day Time
```

3.1 Write a query that outputs the meeting days and times of all employees directly supervised by Oliver Warbucks.

```sql
SELECT m.day, m.time FROM records AS r, meetings AS m
  WHERE r.division = m.division AND
  r.supervisor = "Oliver Warbucks";
```

Video walkthrough

3.2 Write a query that outputs the names of employees whose supervisor is in a different division.

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
SELECT e.name FROM records AS e, records AS s
    WHERE e.supervisor = s.name AND e.division != s.division;

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3.3 Write a query that outputs the names of all pairs of employees that have a meeting at the same time. Make sure that if A|B appears in your output, B|A does not appear as well (A|A and B|B should additionally not appear).

```sql
SELECT e1.name, e2.name FROM records as e1, records as e2, meetings as m1, meetings as m2
WHERE e1.division = m1.division AND e2.division = m2.division AND
   m1.time = m2.time AND AND m1.day = m2.day AND
   e1.name < e2.name;
```

3.4 (Extra question) Will the statement above filter out all redundant output in all cases? Why or why not?

No - if a department has multiple meetings, then all pairs of individuals within that department will be listed multiple times. To avoid this, we can use the `DISTINCT` keyword.

4 Aggregation

So far, we have joined and manipulated individual rows using SELECT statements. But we can also perform aggregation operations over multiple rows with the same SELECT statements.

We can use the `MAX`, `MIN`, `COUNT`, and `SUM` functions to retrieve more information from our initial tables.

If we wanted to find the name and salary of the employee who makes the most money, we might say

```sql
sqlite> SELECT name, MAX(salary) FROM records;
Oliver Warbucks|150000
```

Using the special `COUNT(*)` syntax, we can count the number of rows in our table to see the number of employees at the company.

```sql
sqlite> SELECT COUNT(*) from RECORDS;
9
```

These commands can be performed on specific sets of rows in our table by using the `GROUP BY [column name]` clause. This clause takes all of the rows that have the same value in `column name` and groups them together.

We can find the minimum salary earned in each division of the company.

```sql
sqlite> SELECT division, MIN(salary) FROM records GROUP BY division;
Computer|25000
Administration|25000
Accounting|18000
```

These groupings can be additionally filtered by the `HAVING` clause. In contrast to the `WHERE` clause, which filters out rows, the `HAVING` clause filters out entire groups.

To find all titles that are held by more than one person, we say
SELECT title FROM records GROUP BY title HAVING count(*) > 1;

Questions

Our tables:

records:  Name  Division  Title  Salary  Supervisor
meetings:  Division  Day  Time

4.1 Write a query that outputs each supervisor and the sum of salaries of all the employees they supervise.

SELECT supervisor, SUM(salary) FROM records GROUP BY supervisor;

4.2 Write a query that outputs the days of the week for which fewer than 5 employees have a meeting. You may assume no department has more than one meeting on a given day.

SELECT m.day FROM records AS e, meetings AS m WHERE e.division = m.division GROUP BY m.day HAVING COUNT(*) < 5;

4.3 Write a query that outputs all divisions for which there is more than one employee, and all pairs of employees within that division that have a combined salary less than 100,000.

SELECT e1.division FROM records AS e1, records AS e2
WHERE e1.name != e2.name AND e1.division = e2.division
GROUP BY e1.division HAVING MAX(e1.salary + e2.salary) < 100000;

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
### 5 Extra Questions

Use the following table called `courses` for the questions below:

<table>
<thead>
<tr>
<th>Professor</th>
<th>Course</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan Garcia</td>
<td>CS 61C</td>
<td>Sp19</td>
</tr>
<tr>
<td>John DeNero</td>
<td>CS 61A</td>
<td>Fa18</td>
</tr>
<tr>
<td>Dan Garcia</td>
<td>CS 10</td>
<td>Fa18</td>
</tr>
<tr>
<td>Josh Hug</td>
<td>CS 61B</td>
<td>Sp18</td>
</tr>
<tr>
<td>John DeNero</td>
<td>CS 61A</td>
<td>Sp18</td>
</tr>
<tr>
<td>John DeNero</td>
<td>CS 61A</td>
<td>Fa17</td>
</tr>
<tr>
<td>Paul Hilfinger</td>
<td>CS 61A</td>
<td>Fa17</td>
</tr>
<tr>
<td>Paul Hilfinger</td>
<td>CS 61A</td>
<td>Sp17</td>
</tr>
<tr>
<td>John DeNero</td>
<td>Data 8</td>
<td>Sp17</td>
</tr>
<tr>
<td>Josh Hug</td>
<td>CS 61B</td>
<td>Sp17</td>
</tr>
<tr>
<td>Satish Rao</td>
<td>CS 70</td>
<td>Sp17</td>
</tr>
<tr>
<td>Nicholas Weaver</td>
<td>CS 61C</td>
<td>Sp17</td>
</tr>
<tr>
<td>Gerald Friedland</td>
<td>CS 61C</td>
<td>Sp17</td>
</tr>
</tbody>
</table>

5.1 Create a table called `num_taught` that contains three columns: `professor`, the `course` they taught, and the number of `times` they taught each course.

**Hint:** For this problem, it may help to GROUP BY multiple columns. Multiple columns and full expressions can appear in the group by clause, and groups will be formed for every unique combination of values that result.

```
CREATE TABLE num_taught AS
    SELECT professor AS professor, course AS course, COUNT(*) AS times
    FROM courses
    GROUP BY professor, course;
```

5.2 Write a query that outputs two professors and a course if they have taught that course the same number of times. You may use the `num_taught` table you created in the previous question.

```
SELECT a.professor, b.professor, a.course
FROM num_taught AS a, num_taught AS b
WHERE a.professor > b.professor
    AND a.course = b.course
    AND a.times = b.times;
```

5.3 Write a query that outputs two professors if they co-taught (taught the same course at the same time) the same course more than once.

```
SELECT a.professor, b.professor
FROM courses AS a, courses AS b
WHERE a.professor < b.professor AND
```

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
a.semester = b.semester and a.course = b.course
GROUP BY a.course, a.professor, b.professor HAVING COUNT(*) > 1;
1. Notation notation notation

One annoying thing about Scheme is that it can only understand arithmetic operations that are written in prefix notation. That is, if I want to evaluate an expression, the arithmetic operator must come first, which really goes against everything you were taught as a child. Let’s leverage our interpreter skills to define a Scheme procedure that accepts arithmetic operations with infix notation, which places operators between operands as you’re used to. You only need to support the addition and multiplication operators \( \times \) and \( + \), but you need to support order of operations. Define the \texttt{interpret} procedure so that it passes the test cases below.

```
(scm> (interpret '(1))
1
(scm> (interpret '(1 + 2))
3
(scm> (interpret '(1 * 2))
2
; Order of operations apply
(scm> (interpret '((3 + 2) * 5 + 4))
17
(scm> (interpret '((5 * 3) + 2) * 4))
53
; Parentheses should be handled properly
(scm> (interpret '((3 * (2 + 4))))
24
(scm> (interpret '((3 + (2 + 4))))
9
(scm> (interpret '((3 + 2) + 4))
9
; Parentheses are prioritized higher than order of operations
(scm> (interpret '((1 + 2) * (3 + 4))))
15
(scm> (interpret '((1 + 2) * (3 + 4 * (5 + 6))))
95
```

; Some helper procedures (optional)

```
(define (caar x) (car (car x)))
(define (cadr x) (car (cdr x)))
(define (cddr x) (cdr (cdr x)))

(define (interpret expr)
  (cond
   ((not (list? expr)) expr)
   ((null? (cdr expr)) (if (not (list? (car expr))) (car expr) (interpret (car expr)))))))
   ((list? (car expr)) (interpret (cons (interpret (car expr)) (cddr expr)))))))
   ((eq? '* (cadr expr)) (interpret (cons (* (car expr) (interpret (car (cddr expr))))) (cdr (cddr expr)))))))
   ((eq? '+ (cadr expr)) (+ (car expr) (interpret (cddr expr)))))))))

2. Don’t forget to check your quiz answers, which are on the last page of discussion solutions that are posted at the end of each week.