# Lab 4: Relational Joins and Aggregation

*Due 5 PM, Thursday, March 5, 2020*

In this lab we explore relational joins and aggregation in SQL. We covered in lecture several kinds of joins along with aggregation. So we'll get straight to the lab.

We'll work with two relations: `customers` and `orders`.

The `customers` relation will have the following content:

| id | name |
|---|---|
| 1 | john |
| 2 | sam |
| 3 | sally |
| 4 | paul |
| 5 | liza |

The `orders` relation will have the following records:

| id | customer_id | amount |
|---|---|---|
| 1 | 1 | 20.99 |
| 2 | 1 | 55.00 |
| 3 | 66 | 33.99 |
| 4 | 5 | 190.72 |
| 5 | 4 | 12.33 |

The `customer_id` attribute in the `orders` table is a *foreign key*. It points to the customer associated with an order. For example the order with `id 5` is for `customer` with `id 4` (Paul).

We'll be using the foreign key to *join* the tables together.

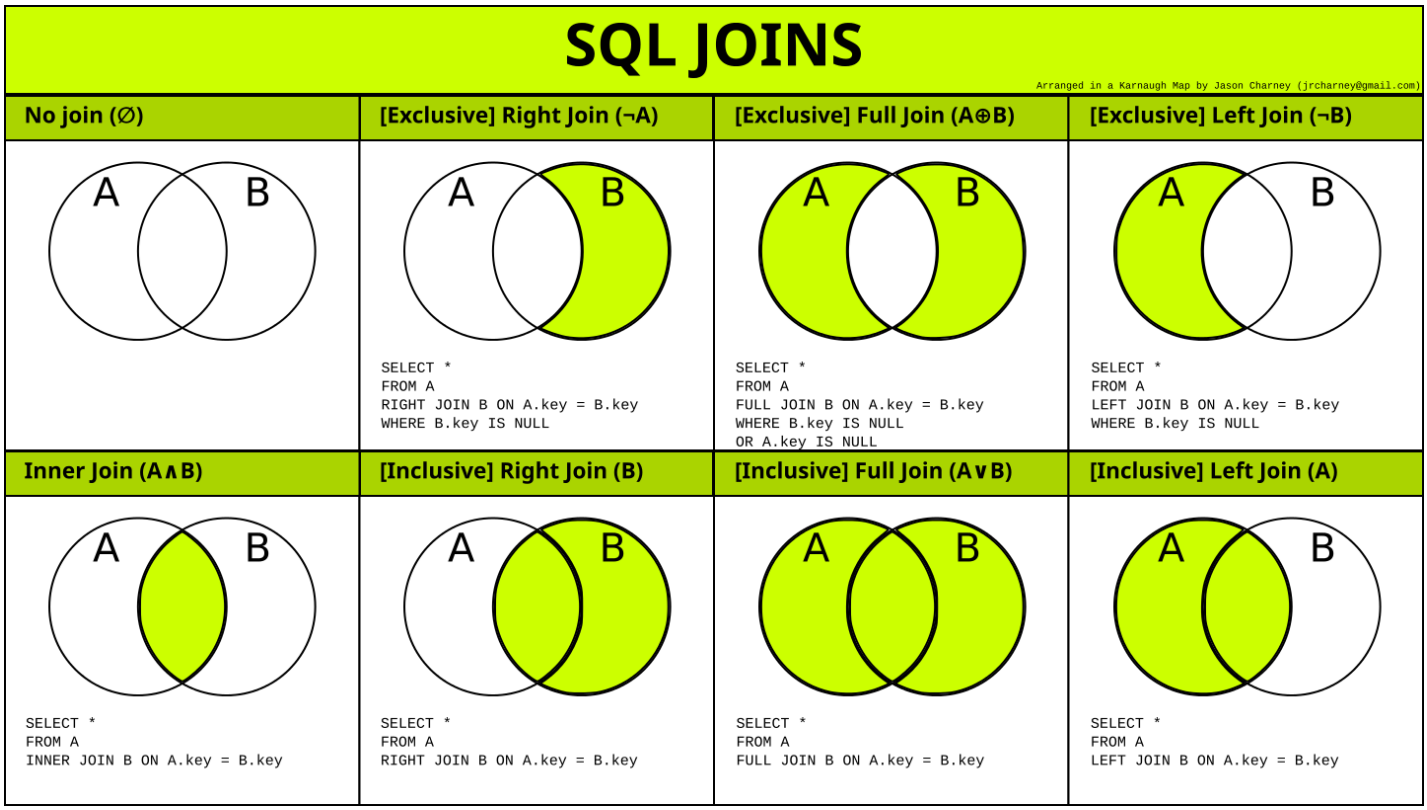
Take a moment to study the two tables. Notice that customer John has multiple orders. But Sam and Sally have no orders.

Conversely, order `3` is a dangling reference. It points to a non-existent customer. (Maybe customer ID `66` was erroneously deleted from the database.)

All the problems below are solved with a single query. You will use some or all of the joins covered in class. Some questions also require the `group_by` clause for aggregating related rows. You will also use *aliasing* to create placeholders for table and column names when joining together two tables.

> **Important**
>
> SQLite does not support the full complement of joins we cover in class. Nonetheless, it's possible to do all the problems with the joins it does support.
>
> Some problems require a right join, which is missing in SQLite. You can simulate a right join by swapping left and right relations in the query.
>
> Refer to the SQLite documentation (https://www.sqlite.org/syntax/join-clause.html) for the supported forms of the join clause.

You might find this pictorial summary of the various joins helpful:




## Preliminaries: Setup and Imports

In [1]:

```
import sqlalchemy
from sqlalchemy import create_engine
from sqlalchemy import inspect

import pandas as pd
import unittest
import math
from IPython.display import display, HTML
```

### Open Database and Create Tables

In the following snippet we create the database in the system temporary directory `/tmp`. You can move the database elsewhere if you like.

I highly recommend opening the database from the `sqlite3` console tool like so:

```
$ sqlite3 /tmp/customers.db
```

Once inside the database, you can issue SQL commands directly. For example:

```
sqlite> select * from customers;
id          name
----------  ----------
1           john
2           sam
3           sally
4           paul
5           liza
```

It may be easier to learn the various forms by playing around with SQL statements like I do above. Try out various commands. See if it matches your expectations for the statement.

In [2]:

```
db_name = 'sqlite:////tmp/customers.db'


engine = create_engine(db_name, echo=False)
print(sqlalchemy.__version__)
print(engine)
```

```
1.3.13
Engine(sqlite:////tmp/customers.db)
```

## Create the Customer Table

In [3]:

```
drop_table_statement = """drop table if exists customers"""
engine.execute(drop_table_statement)

# sql statement
create_table_stmt = """create table customers(
  id integer primary key,
  name text not null
);
"""
engine.execute(create_table_stmt)
```

Out[3]:

```
<sqlalchemy.engine.result.ResultProxy at 0x7f5f891661d0>
```

## Populate the Customer Table

In [4]:

```
customer_list = [
    "john", "sam", "sally", "paul", "liza"
]

insert_statement = """
insert into customers (name)
  values(?)
"""

for c in customer_list:
    print(f"inserting {c}")
    # insert into db; note unpacking of tuple (*c)
    engine.execute(insert_statement, c)
```

```
inserting john
inserting sam
inserting sally
inserting paul
inserting liza
```

## Read the Customer Table

Here is what the `customers` table looks like.

Notice that we're using Pandas `read_sql` method to insert the result directly into a DataFrame. This will let us pretty print the table and also run assertions in the unit tests that go with each problem.

In [5]:

```
d = pd.read_sql("select * from customers", engine)
d
```

Out[5]:

| | id | name |
|---|---|---|
| **0** | 1 | john |
| **1** | 2 | sam |
| **2** | 3 | sally |
| **3** | 4 | paul |
| **4** | 5 | liza |

## Create the Orders Table

In [6]:

```
drop_orders_statement = """drop table if exists orders"""
engine.execute(drop_orders_statement)

# sql statement
create_orders_table_stmt = """create table orders(
  id integer primary key,
  customer_id integer,
  amount float not null
);
"""
engine.execute(create_orders_table_stmt)
```

Out[6]:

```
<sqlalchemy.engine.result.ResultProxy at 0x7f5f4707ae10>
```

## Populate the Orders Table

In [7]:

```
orders_list = [
    (20.99, 1),
    (55.00, 1),
    (33.99, 66),
    (190.72, 5),
    (12.33, 4)
]

insert_orders_statement = """
insert into orders (amount, customer_id)
  values(?,?)
"""

for o in orders_list:
    print(f"inserting {o[0]}")
    # insert into db; note unpacking of tuple (*o)
    engine.execute(insert_orders_statement, o)
```

```
inserting 20.99
inserting 55.0
inserting 33.99
inserting 190.72
inserting 12.33
```

## Read the Orders Table

In [8]:

```
d = pd.read_sql("select * from orders", engine)

d
```

Out[8]:

| | id | customer_id | amount |
|---|---|---|---|
| **0** | 1 | 1 | 20.99 |
| **1** | 2 | 1 | 55.00 |
| **2** | 3 | 66 | 33.99 |
| **3** | 4 | 5 | 190.72 |
| **4** | 5 | 4 | 12.33 |

# Homework

*60 Points Total*

## Problem 1: List Orders For Each Customer

*10 Points*

List all orders for each customer. Return a relation with the following columns:

| customer_id | name | order_id | Amount |
|---|---|---|---|
| Customer ID | Customer Name | Order ID | Order Amount |

The above relation will **not** include rows for customers that don't have associated orders.

In this and all subsequent problemsyou should fill in the `query` variable in the `setUpClass` method of the unit test. The test code is written for you and will ascertain whether your query meets the specification.

### Aliasing

You will almost certainly use table and attribute **aliasing**. Aliasing can help shorten SQL statements. But more importantly, they *disambiguate* field/attribute names in joins where the joined tables have attributes with the same name. Often, we want to disambiguate IDs, the primary key.

Consider two examples:

```
select c.id, c.name from customers as c;
```

In the above `customers d` creates an alias `c` for `customers`. This alias can then be used to dereference column names (`c.id`, `c.name`).

In the above context an alias is hardly useful. You could have done the same with `select id, name from customers`. But aliases come into their own when multiple tables are involved and you need to disambiguate or rename common attributes. So, for example when joining `customers` and `orders` both tables have an `ID` key. We can use aliases to rename the `ID` attributes so they don't clash:

```
select c.id as customer_id, c.name as customer_name, o.id as order_id
    from customers as c
    join orders as o
    on o.customer_id = c.id
```

In [9]:

```
class Problem1Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT c.id AS id, c.name AS name, o.id AS order_id, o.amount AS amount
            FROM customers AS c
            JOIN orders AS o
            WHERE o.customer_id = c.id
        """#do a left inner join (w/ no nulls)
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df
        self.assertTrue(type(df))
        self.assertEqual(len(df), 4)

        keys = df.keys()
        self.assertIn('id', keys)
        self.assertIn('name', keys)
        self.assertIn('order_id', keys)
        self.assertIn('amount', keys)

        # john should have two orders
        self.assertEqual(len(df[df['name'] == 'john']), 2)

        # sally won't be in the results
        x = df['name'] == 'sally'
        self.assertNotIn(True, enumerate(x))

        # sam won't be in the results
        x = df['name'] == 'sam'
        self.assertNotIn(True, enumerate(x))


# Run the unit tests
unittest.main(defaultTest="Problem1Test", argv=['ignored', '-v'], exit=False)
```

| | id | name | order_id | amount |
|---|---|---|---|---|
| **0** | 1 | john | 1 | 20.99 |
| **1** | 1 | john | 2 | 55.00 |
| **2** | 5 | liza | 4 | 190.72 |
| **3** | 4 | paul | 5 | 12.33 |

```
test_query (__main__.Problem1Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.016s

OK
```

Out[9]:

```
<unittest.main.TestProgram at 0x7f5f4701b490>
```

## Problem 2: List Customers With No Orders

*10 Points*

List all customers for which no orders exist. The resulting relation will have the following format:

| id | name |
|---|---|
| Customer ID | Customer Name |

In [82]:

```
class Problem2Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT c.id AS id, c.name AS name, o.id AS order_id, o.amount AS amount
            FROM customers AS c
            LEFT JOIN orders AS o
            ON o.customer_id = c.id
            WHERE amount IS NULL

        """
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df

        self.assertEqual(len(df), 2)

        keys = df.keys()
        self.assertIn('id', keys)
        self.assertIn('name', keys)

        self.assertTrue((df['name'] == 'sally').any)
        self.assertTrue((df['name'] == 'sam').any)


# Run the unit tests
unittest.main(defaultTest="Problem2Test", argv=['ignored', '-v'], exit=False)
```

| | id | name | order_id | amount |
|---|---|---|---|---|
| **0** | 2 | sam | None | None |
| **1** | 3 | sally | None | None |

```
test_query (__main__.Problem2Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.010s

OK
```

Out[82]:

```
<unittest.main.TestProgram at 0x7f5f46dabe10>
```

In [84]:

```
pd.read_sql?
```

```
Signature:
pd.read_sql(
    sql,
    con,
    index_col=None,
    coerce_float=True,
    params=None,
    parse_dates=None,
    columns=None,
    chunksize=None,
)
Docstring:
Read SQL query or database table into a DataFrame.

This function is a convenience wrapper around ``read_sql_table`` and
``read_sql_query`` (for backward compatibility). It will delegate
to the specific function depending on the provided input. A SQL query
will be routed to ``read_sql_query``, while a database table name will
be routed to ``read_sql_table``. Note that the delegated function might
have more specific notes about their functionality not listed here.

Parameters
----------
sql : string or SQLAlchemy Selectable (select or text object)
    SQL query to be executed or a table name.
con : SQLAlchemy connectable (engine/connection) or database string URI
    or DBAPI2 connection (fallback mode)

    Using SQLAlchemy makes it possible to use any DB supported by that
    library. If a DBAPI2 object, only sqlite3 is supported.
index_col : string or list of strings, optional, default: None
    Column(s) to set as index(MultiIndex).
coerce_float : boolean, default True
    Attempts to convert values of non-string, non-numeric objects (like
    decimal.Decimal) to floating point, useful for SQL result sets.
params : list, tuple or dict, optional, default: None
    List of parameters to pass to execute method.  The syntax used
    to pass parameters is database driver dependent. Check your
    database driver documentation for which of the five syntax styles,
    described in PEP 249's paramstyle, is supported.
    Eg. for psycopg2, uses %(name)s so use params={'name' : 'value'}
parse_dates : list or dict, default: None
    - List of column names to parse as dates.
    - Dict of ``{column_name: format string}`` where format string is
      strftime compatible in case of parsing string times, or is one of
      (D, s, ns, ms, us) in case of parsing integer timestamps.
    - Dict of ``{column_name: arg dict}``, where the arg dict corresponds
      to the keyword arguments of :func:`pandas.to_datetime`
      Especially useful with databases without native Datetime support,
      such as SQLite.
columns : list, default: None
    List of column names to select from SQL table (only used when reading
    a table).
chunksize : int, default None
    If specified, return an iterator where `chunksize` is the
    number of rows to include in each chunk.

Returns
-------
DataFrame

See Also
--------
read_sql_table : Read SQL database table into a DataFrame.
read_sql_query : Read SQL query into a DataFrame.
File:      /srv/conda/envs/notebook/lib/python3.7/site-packages/pandas/io/sql.py
Type:      function
```

## Problem 3: Associate Customer Name with Orders

*10 Points*

For each `order` list the customer name associated with the order. If no customer exists for an order omit the row.

The resulting relation will have the following attributes:

| order_id | customer_name | amount |
|---|---|---|
| Order ID | Customer Name | Order Amount |

In [86]:

```
class Problem3Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT  o.id AS order_id, c.name AS customer_name, o.amount AS amount
            FROM customers AS c
            LEFT JOIN orders AS o
            WHERE o.customer_id = c.id

        """
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df

        self.assertEqual(len(df), 4)

        keys = df.keys()
#         self.assertIn('id', keys)
        self.assertIn('order_id', keys)
        self.assertIn('customer_name', keys)
        self.assertIn('amount', keys)

        for name in ['john', 'liza', 'paul']:
            self.assertTrue((df['customer_name'] == name).any)


# Run the unit tests
unittest.main(defaultTest="Problem3Test", argv=['ignored', '-v'], exit=False)
```

| | order_id | customer_name | amount |
|---|---|---|---|
| **0** | 1 | john | 20.99 |
| **1** | 2 | john | 55.00 |
| **2** | 4 | liza | 190.72 |
| **3** | 5 | paul | 12.33 |

```
test_query (__main__.Problem3Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.010s

OK
```

Out[86]:

```
<unittest.main.TestProgram at 0x7f5f46daf750>
```

## Problem 4: List Orders Per Customers, Include Customers Without Orders

*10 Points*

For each customer, list the orders associated with the customer. However, in the case where a customer does not have any orders include the customer in the output relation.

| customer_id | customer_name | order_id | amount |
|---|---|---|---|
| Customer ID | Customer Name | Order ID | Order Amount |

Some customers (e.g., John) have multiple orders. Others have none. In contrast with the problem above, also include the customers that don't have any rows in the result. These rows will have NULL values for their respective `order_id` and `amount` attributes.

In [108]:

```
class Problem4Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT c.id AS customer_id, c.name AS customer_name,  o.id AS order_id, o.amount AS amount
            FROM customers AS c
            LEFT JOIN orders AS o
            ON o.customer_id = c.id


        """
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df
        self.assertTrue(type(df))
        self.assertEqual(len(df), 6)

        keys = df.keys()
        self.assertIn('customer_id', keys)
        self.assertIn('customer_name', keys)
        self.assertIn('order_id', keys)
        self.assertIn('amount', keys)

        # john should have two orders
        self.assertEqual(len(df[df['customer_name'] == 'john']), 2)

        for name in ['sam', 'sally']:
            r = df[df['customer_name'] == name].iloc[0]
            self.assertTrue(math.isnan(r['order_id']))
            self.assertTrue(math.isnan(r['amount']))


# Run the unit tests
unittest.main(defaultTest="Problem4Test", argv=['ignored', '-v'], exit=False)
```

| | customer_id | customer_name | order_id | amount |
|---|---|---|---|---|
| **0** | 1 | john | 1.0 | 20.99 |
| **1** | 1 | john | 2.0 | 55.00 |
| **2** | 2 | sam | NaN | NaN |
| **3** | 3 | sally | NaN | NaN |
| **4** | 4 | paul | 5.0 | 12.33 |
| **5** | 5 | liza | 4.0 | 190.72 |

```
test_query (__main__.Problem4Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.015s

OK
```

Out[108]:

```
<unittest.main.TestProgram at 0x7f5f46d05450>
```

## Problem 5: Compute Total Amount Spent Per Customer

For each customer, list the `total` spend for that customer. That is you will sum the totals for each order by a customer. If a customer does not have any associated orders, print `0`. The resulting relation will have a single row for each customer in the customers table.

The output table will have the following attributes:

| customer_id | customer_name | order_count | total |
|---|---|---|---|
| Order ID | Customer Name | Number of orders per customer | Total Amount Spent or `0` |

You should use the SQL `coalesce` function (https://www.w3schools.com/sql/func_sqlserver_coalesce.asp) to replace a NULL value for `total` with a zero.

Use the `count` (https://www.w3schools.com/sql/sql_count_avg_sum.asp) function to compute the number of orders per customer

In [109]:

```
class Problem5Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT c.id AS customer_id, c.name AS customer_name,  count(o.id) AS order_count,
                COALESCE(sum(o.amount),0) AS total
            FROM customers AS c
            LEFT JOIN orders AS o
            ON o.customer_id = c.id
            GROUP BY c.name
        """
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df
        self.assertTrue(type(df))
        self.assertEqual(len(df), 5)

        keys = df.keys()
        self.assertIn('customer_id', keys)
        self.assertIn('customer_name', keys)
        self.assertIn('order_count', keys)
        self.assertIn('total', keys)

        expected = {
            'john': (2, 75.99),
            'sam': (0, 0.00),
            'sally': (0, 0.00),
            'paul': (1, 12.33),
            'liza': (1, 190.72),
        }

        for name, val in expected.items():
            cnt = val[0]
            total = val[1]
            r = df[df['customer_name'] == name].iloc[0]
            self.assertEqual(r['order_count'], cnt)
            self.assertEqual(r['total'], total)



# Run the unit tests
unittest.main(defaultTest="Problem5Test", argv=['ignored', '-v'], exit=False)
```

| | customer_id | customer_name | order_count | total |
|---|---|---|---|---|
| **0** | 1 | john | 2 | 75.99 |
| **1** | 5 | liza | 1 | 190.72 |
| **2** | 4 | paul | 1 | 12.33 |
| **3** | 3 | sally | 0 | 0.00 |
| **4** | 2 | sam | 0 | 0.00 |

```
test_query (__main__.Problem5Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.015s

OK
```

Out[109]:

```
<unittest.main.TestProgram at 0x7f5f46ceb6d0>
```

## Problem 6: Find Customers Who Spent More than $70

*10 Points*

This problem is identical to the one above, except that you will filter out customers who spent less in total than $70. As above, your result relation will have the following columns:

| customer_id | customer_name | order_count | total |
|---|---|---|---|
| Order ID | Customer Name | Number of orders per customer | Total Amount Spent or 0 |

In [116]:

```
class Problem6Test(unittest.TestCase):

    @classmethod
    def setUpClass(cls):
        query = """
            SELECT c.id AS customer_id, c.name AS customer_name,  count(o.id) AS order_count,
                COALESCE(sum(o.amount),0) AS total
            FROM customers AS c
            LEFT JOIN orders AS o
            ON o.customer_id = c.id
            GROUP BY c.name
            HAVING total > 70
        """
        cls.df = pd.read_sql(query, engine)
        display(cls.df)

    def test_query(self):

        df = self.df
        self.assertTrue(type(df))
        self.assertEqual(len(df), 2)

        keys = df.keys()
        self.assertIn('customer_id', keys)
        self.assertIn('customer_name', keys)
        self.assertIn('order_count', keys)
        self.assertIn('total', keys)

        expected = {
            'john': (2, 75.99),
            'liza': (1, 190.72),
        }

        for name, val in expected.items():
            cnt = val[0]
            total = val[1]
            r = df[df['customer_name'] == name].iloc[0]
            self.assertEqual(r['order_count'], cnt)
            self.assertEqual(r['total'], total)



# Run the unit tests
unittest.main(defaultTest="Problem6Test", argv=['ignored', '-v'], exit=False)
```

| | customer_id | customer_name | order_count | total |
|---|---|---|---|---|
| **0** | 1 | john | 2 | 75.99 |
| **1** | 5 | liza | 1 | 190.72 |

```
test_query (__main__.Problem6Test) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.015s

OK
```

Out[116]:

```
<unittest.main.TestProgram at 0x7f5f46d7e610>
```