# What is Data Retrieval?

SDSC SAN DIEGO SUPERCOMPUTER CENTER

## What is Data Retrieval?

- **Data retrieval**
  - The way in which the desired data is specified and retrieved from a data store
- **Our focus**
  - How to specify a data request
    - For static and streaming data
  - The internal mechanism of data retrieval
    - For large and streaming data

## What is a Query Language?

- A language to specify the data items you need
- A query language is declarative
  - Specify what you need rather than how to obtain it
  - SQL (Structured Query Language)
- Database programming language
  - Procedural programming language
  - Embeds query operations

# SQL

- **The standard for structured data**
  - Oracle's SQL to Spark SQL
- **Example Database Schema**

**Bars(<u>name</u>, addr, license)**
**Beers(<u>name</u>, manf)**
**Sells(<u>bar</u>, <u>beer</u>, price)**
**Drinkers(<u>name</u>, addr, phone)**
**Frequents(<u>drinker</u>, <u>bar</u>)**
**Likes(<u>drinker</u>, <u>beer</u>)**

| <u>name</u> | <u>addr</u> | license |
|---|---|---|
| Great American Bar | 363 Main St., SD, CA 92390 | 41-437844098 |
| Beer Paradise | 6450 Mango Drive, SD, CA 92130 | 41-973428319 |
| Have a Good Time | 8236 Adams Avenue, SD, CA 92116 | 32-032263401 |

## SELECT-FROM-WHERE

- Which beers are made by Heineken?

```
SELECT name
FROM Beers
WHERE manf = 'Heineken'
```

*Output attribute(s)*

*Table(s) to use*

*The condition(s) to satisfy*

*Strings like 'Heineken' are case-sensitive and are put in quotes*

| name |
|---|
| Heineken Lager Beer |
| Amstel Lager |
| Amstel Light |
| … |

*Select* $_{manf=\text{'Heineken'}}$ *(Beers)*

$\Downarrow$

*Project(name)*

# More Example Queries

- **Find expensive beer**
  - SELECT DISTINCT beer, price
  - FROM Sells
  - WHERE price > 15
- **Which businesses have a Temporary License (starts with 32) in San Diego?**
  - SELECT name
  - FROM Bars
  - WHERE addr LIKE '%SD%' **AND** license LIKE '32%' LIMIT 5

| name | addr | license |
|---|---|---|
| Great American Bar | 363 Main St., SD, CA 92390 | 41-437844098 |
| Beer Paradise | 6450 Mango Drive, SD, CA 92130 | 41-973428319 |
| Have a Good Time | 8236 Adams Avenue, SD, CA 92116 | 32-032263401 |

## Select-Project Queries in the Large

- **Large Tables can be partitioned**
  - Many partitioning schemes
    - Range partitioning on primary key

| name | manf |
|---|---|
| A… | Gambrinus |
| A… | Heineken |
| … | |
| B… | Anheuser-Busch |

*Machine 1*

| name | manf |
|---|---|
| C… | MillerCoors |
| C… | MillerCoors |
| … | |
| D… | Duvel Moortgat |

*Machine 2*

…

| name | manf |
|---|---|
| H… | Heineken |
| H… | Pabst |
| … | |
| H… | Anheuser-Busch |

*Machine 5*

…

# Select-Project Queries in the Large

| name | manf |
|---|---|
| A… | Gambrinus |
| A… | Heineken |
| … | |
| B… | Anheuser-Busch |

*Machine 1*

| name | manf |
|---|---|
| C… | MillerCoors |
| C… | MillerCoors |
| … | |
| D… | Duvel Moortgat |

*Machine 2*

…

| name | manf |
|---|---|
| H… | Heineken |
| H… | Pabst |
| … | |
| H… | Anheuser-Busch |

*Machine 5*

…

```
SELECT *                        pattern
FROM Beers
WHERE name like 'Am%'
```

```
SELECT name
FROM Beers
WHERE manf = 'Heineken'
```

- **Two queries**
  - Find records for beers whose name starts with 'Am'
  - Which beers are made by Heineken?

# Evaluating SP Queries for Large Data

| name | manf |
|---|---|
| A… | Gambrinus |
| A… | Heineken |
| … | |
| B… | Anheuser-Busch |

*Machine 1*

| name | manf |
|---|---|
| C… | MillerCoors |
| C… | MillerCoors |
| … | |
| D… | Duvel Moortgat |

*Machine 2*

…

| name | manf |
|---|---|
| H… | Heineken |
| H… | Pabst |
| … | |
| H… | Anheuser-Busch |

*Machine 5*

…

```
SELECT *
FROM Beers
WHERE name like 'Am%'
```

- A query processing trick
  - Use the partitioning information
    - Just use partition 1!!

# Evaluating SP Queries for Large Data

| name | manf |
|---|---|
| A… | Gambrinus |
| A… | Heineken |
| … | |
| B… | Anheuser-Busch |

*Machine 1*

| name | manf |
|---|---|
| C… | MillerCoors |
| C… | MillerCoors |
| … | |
| D… | Duvel Moortgat |

*Machine 2*

…

| name | manf |
|---|---|
| H… | Heineken |
| H… | Pabst |
| … | |
| H… | Anheuser-Busch |

*Machine 5*

…

***SELECT*** *name*
***FROM*** *Beers*
***WHERE*** *manf = 'Heineken'*

*Broadcast query*

*In each machine in parallel:*
*Select $_{\text{manf='Heineken'}}$(Beers)*
*Project(name)*

*Gather Partial Results*
*Union*
*Return*

# Local and Global Indexing

- What if a machine does not have any data for the query attributes?
- Index structures
  - Given value, return records
  - Several solutions
    - Use local index on each machine
    - Use a machine index for each value
    - Use a combined index in a global index server

| manf | RecordIDs |
|---|---|
| … | … |
| MillerCoors | 34, 35, 87, 129, … |
| Duvel Moortgat | 5, 298, 943, 994,… |
| Heineken | 631, 683, 882,… |
| … | … |

| manf | machineIDs |
|---|---|
| … | … |
| MillerCoors | 10 |
| Duvel Moortgat | 3, 4 |
| Heineken | 1, 3, 5 |
| … | … |

## Pause

# Querying Two Relations

- Often we need to combine two relations for queries
  - Find the beers liked by drinkers who frequent The Great American Bar
- In SQL

```
    SELECT DISTINCT beer
    FROM Likes L, Frequents F
    WHERE bar = The Great American Bar’ AND
          F.drinker = L.drinker
```

*Frequents(drinker, bar)*
*Likes(drinker, beer)*

# SPJ Queries

*Frequents(drinker, bar)*
*Likes(drinker, beer)*

```
SELECT DISTINCT beer
FROM Likes L, Frequents F
WHERE bar = 'The Great American Bar'
      AND F.drinker = L.drinker
```

- **Steps**

  Selection $_{\text{bar = 'The Great American Bar'}}$ (Frequents)

  ↓ ← *No intermediate storage*

  Join $_{\text{F.drinker = L.drinker}}$ ( _, Likes)

  ↓ ← *R(drinker, beer)*

  Project $_{\text{beer}}$(_)

  ↓

  Deduplicate(_)

  ↓

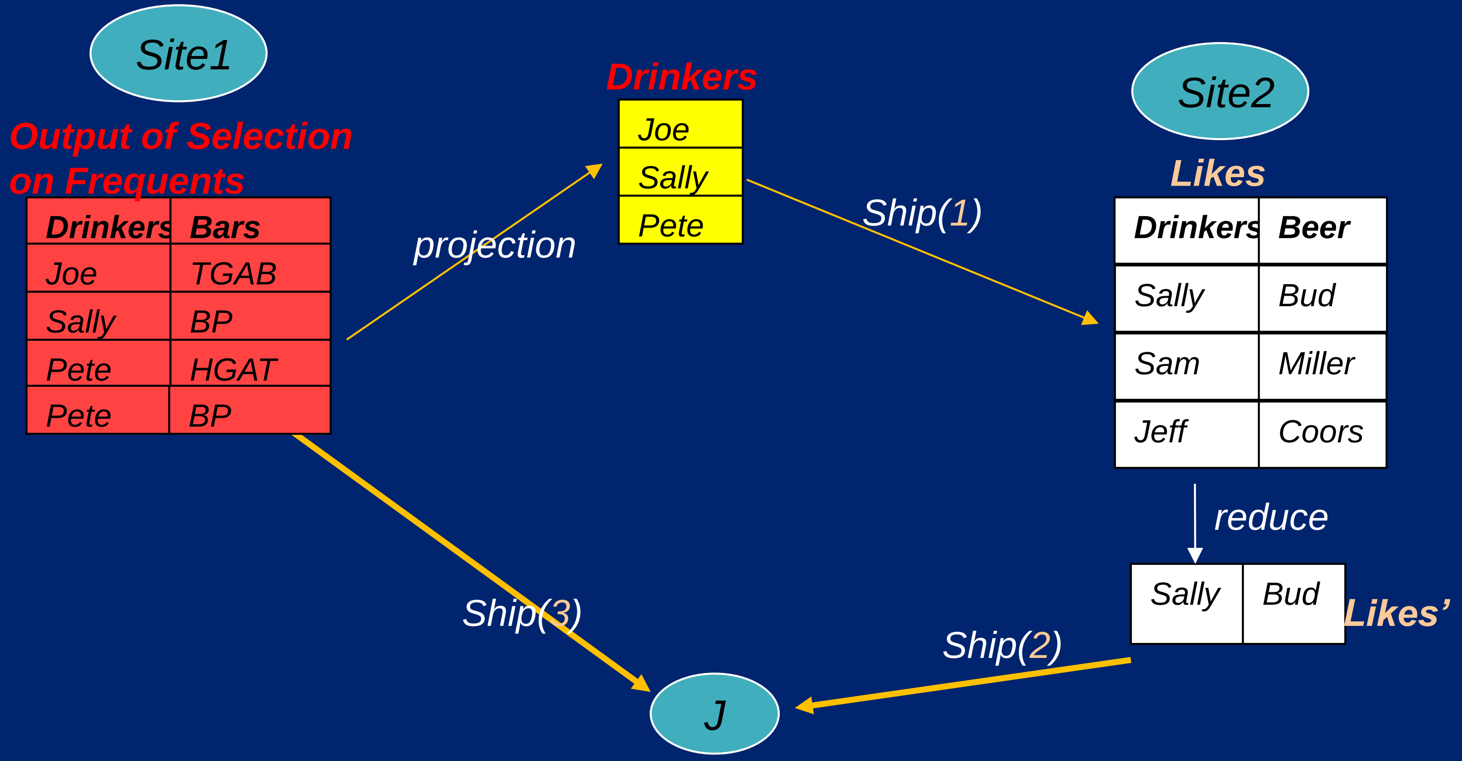
  Output

# Join in a Distributed Setting

*Frequents(drinker, bar)*
*Likes(drinker, beer)*

- **Semijoin**
  - A semijoin from R to S on attribute is used to reduce the data transmission cost
  - Computing steps:
    - **Project** R on attribute A and call it (R[A] ) – the Drinkers column
    - **Ship** this projection ( a semijoin projection) from the site of R to the site of S
    - **Reduce** S to S' by eliminating tuples where attribute A are not matching any value in R[A]

## Semijoin s: Frequents—Drinkers→Likes



Output of Selection on Frequents

| Drinkers | Bars |
|---|---|
| Joe | TGAB |
| Sally | BP |
| Pete | HGAT |
| Pete | BP |

Drinkers

| |
|---|
| Joe |
| Sally |
| Pete |

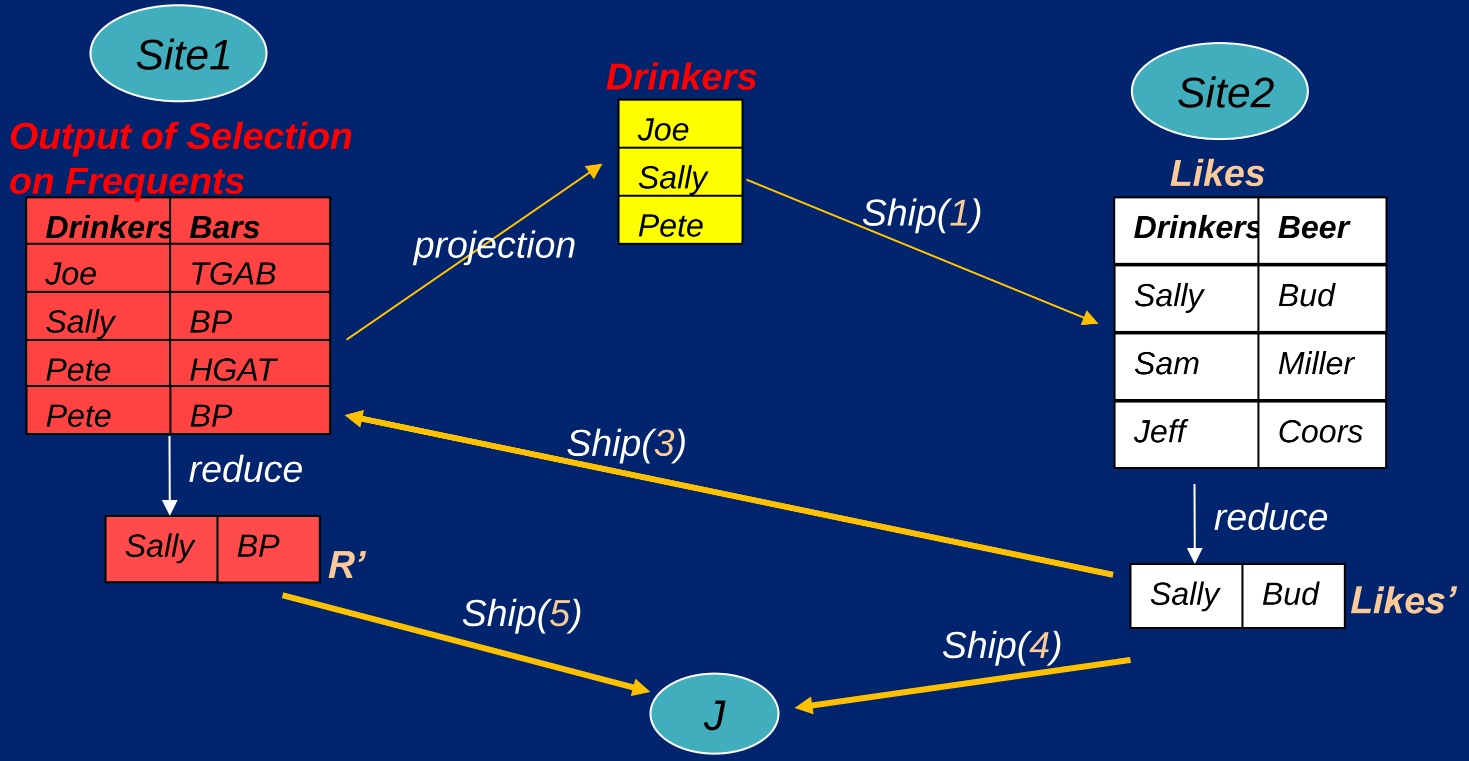
Likes

| Drinkers | Beer |
|---|---|
| Sally | Bud |
| Sam | Miller |
| Jeff | Coors |

Likes'

| | |
|---|---|
| Sally | Bud |

## *Semijoin s: Frequents—Drinkers →Likes*



**Output of Selection on Frequents**

| **Drinkers** | **Bars** |
|---|---|
| Joe | TGAB |
| Sally | BP |
| Pete | HGAT |
| Pete | BP |

**Drinkers**

| |
|---|
| Joe |
| Sally |
| Pete |

**Likes**

| **Drinkers** | **Beer** |
|---|---|
| Sally | Bud |
| Sam | Miller |
| Jeff | Coors |

**R'**

| | |
|---|---|
| Sally | BP |

**Likes'**

| | |
|---|---|
| Sally | Bud |

## Pause

# Subqueries

- A slightly complex query
- Find the bars that serve Miller for the same or less price than what TGAB charges for Bud
- We may break it into two queries:
  1. Find the price TGAB charges for Bud
  2. Find the bars that serve Miller at that price

# Subqueries in SQL

```
SELECT bar
FROM Sells
WHERE beer = ’Miller’ AND
      price <= (SELECT price
                 FROM Sells
                 WHERE bar = ’TGAB’
                AND beer = ’Bud’);
```

*The price at which TGAB sells Bud*

## Subqueries with IN

- Find the name and manufacturer of each beer that Fred does not like
- Query

```
SELECT *
FROM Beers
WHERE name NOT IN
                 (  SELECT beer
                         FROM Likes
                       WHERE drinker = 'Fred');
```

*Beers(name, manf)*
*Likes(drinker, beer)*

# Correlated Subqueries

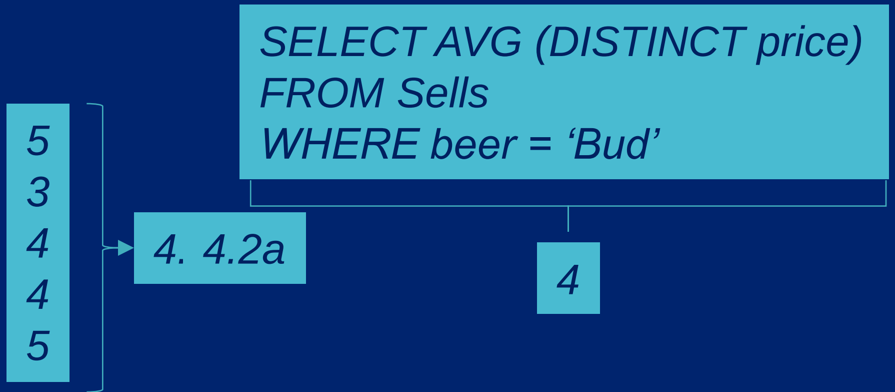
- **Find the name and price of each beer that is more expensive than the average price of beers sold in the bar**

```
SELECT beer, price
FROM  Sells s1
WHERE price >
    (SELECT AVG(price)
     FROM Sells s2
     WHERE s1.bar = s2.bar)
```

| Bar | Beer | Price |
|---|---|---|
| HGAT | Bud | 5 |
| BP | Michelob | 4 |
| TGAB | Heineken | 6 |
| HGAT | Guinness | 10 |

## Aggregate Queries

- Example
  - Find the average price of Bud:
  - SELECT AVG(price)
  - FROM Sells
  - WHERE beer = ’Bud’;
- Other aggregate functions
  - SUM, MIN, MAX, COUNT, …



```
SELECT AVG (DISTINCT price)
FROM Sells
WHERE beer = ‘Bud’
```

## GROUP BY Queries

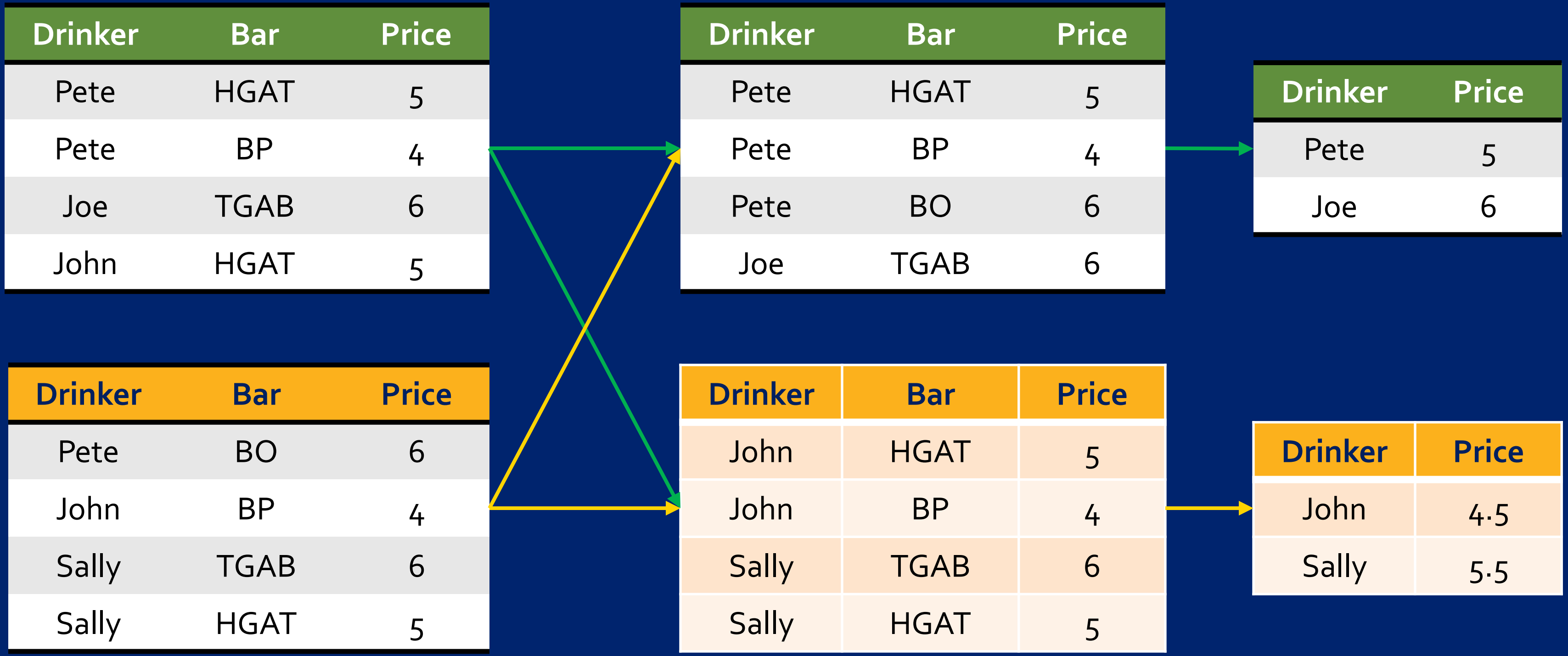
- Find for each drinker the average price of Bud at the bars they frequent

```
SELECT drinker, AVG(price)
FROM Frequents, Sells
WHERE beer = 'Bud' AND
      Frequents.bar = Sells.bar
GROUP BY drinker;
```

| Drinker | Bar | Price |
|---|---|---|
| Pete | HGAT | 5 |
| Pete | BP | 4 |
| Joe | TGAB | 6 |
| Joe | HGAT | 5 |

| Drinker | Price |
|---|---|
| Pete | 4.5 |
| Joe | 5.5 |

# Grouping Aggregates over Partitioned Data



| Drinker | Bar | Price |
|---|---|---|
| Pete | HGAT | 5 |
| Pete | BP | 4 |
| Joe | TGAB | 6 |
| John | HGAT | 5 |

| Drinker | Bar | Price |
|---|---|---|
| Pete | BO | 6 |
| John | BP | 4 |
| Sally | TGAB | 6 |
| Sally | HGAT | 5 |

| Drinker | Bar | Price |
|---|---|---|
| Pete | HGAT | 5 |
| Pete | BP | 4 |
| Pete | BO | 6 |
| Joe | TGAB | 6 |

| Drinker | Bar | Price |
|---|---|---|
| John | HGAT | 5 |
| John | BP | 4 |
| Sally | TGAB | 6 |
| Sally | HGAT | 5 |

| Drinker | Price |
|---|---|
| Pete | 5 |
| Joe | 6 |

| Drinker | Price |
|---|---|
| John | 4.5 |
| Sally | 5.5 |