SQL

SQL tutorial:
http://www.w3schools.com/sql/default.asp

Outline

- Why databases?
- What is a database anyway?
  - History of databases
- Important DMBS features
- Relational data model
  - Why its great
  - What it looks like (SQL)

Why Databases?

- In the early days, database applications were built on top of ***file systems***.

- Drawbacks of using file systems to store data:
  - **Data redundancy and inconsistency**
    - Multiple file formations, duplication of information in different files
  - **Difficulty in accessing data**
    - Need to write a new program to carry out each new task
  - **Data Isolation** – multiple files and formats
  - **Integrity problems**
    - Enforcing integrity constraints
    - Adding / changing existing constraints

Why Databases?

- Drawbacks of using file systems (cont.)
  - **Atomicity of updates**
    - Failures may leave database in an inconsistent state with partial updates carried out
  - **Concurrent access by multiple users**
    - Concurrent accessed needed for performance
    - Uncontrolled concurrent accesses can lead to inconsistencies
      - i.e. Two people reading a balance and updating it at the same time
  - **Security problems**

Students

Name, Year, Major, Enrollment
Mary Jane, 2017 , CS , [CS135 – Web Dev, CS133 - DB, CS181-Big Data]
John Smith , 2018 , Math , [Math105 – Linear Alg, CS135- Web Dev]
Erin Key , 2017 , Econ , [CS181 – Big Data, CS133- DB]
…

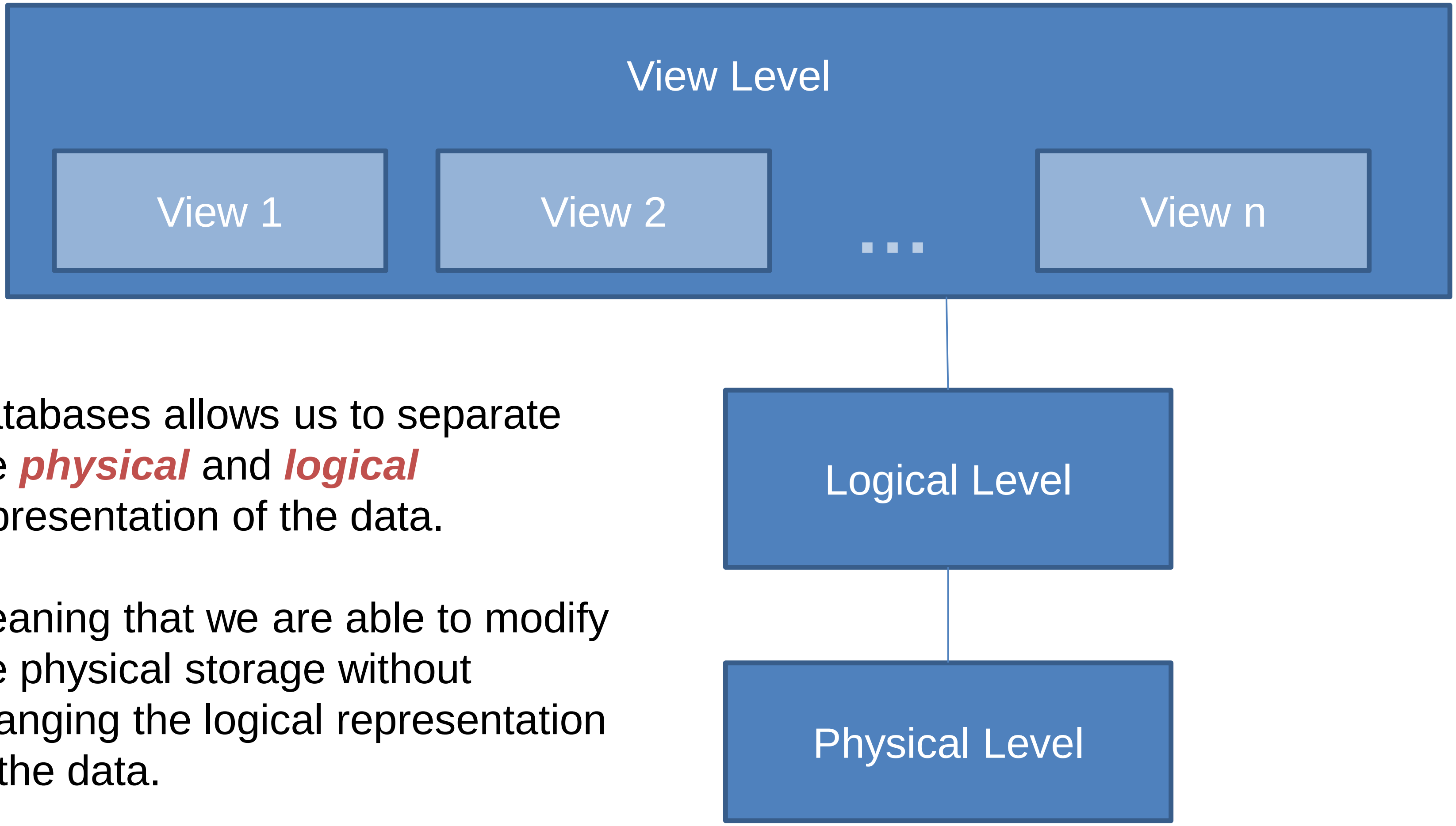
- What we add/remove courses, or update course information such as name? … we would need to update in all relevant places!!
- What if we want to answer the query “How many students are registered for CS 133? ... The programmer has to write specific code to form the query!
- What if we want to enforce constraint that each student is registered for at least 1 course? ... Its hard to enforce as students add/drop, and courses are cancleled and added continuously.

Database systems offer solutions to all the above problems

Timeline of Databases

- **1960s** – hierarchical databases which provided support for concurrency, recover, and fast access.
- **1970-1972** - Edgar Codd who was working at IBM proposed the ‘relational database model’. Provided support for more reliability, less redundancy, more flexibility, etc.
- **1970s** – two major RDBMS prototypes were proposed: Ingres and System R
- **Mid 1970s** – A DB model called Entity –Relationship(ER) was proposed
- **1980s** – Structured Query Language (SQL) became standard querying language.
- **Late 1980s - 1990s** – Parallel and distributed databases
- **2000s & Now** – NoSQL databases

Architecture of Databases



- Databases allows us to separate the ***physical*** and ***logical*** representation of the data.

- Meaning that we are able to modify the physical storage without changing the logical representation of the data.

Relational DBMS to the rescue

- Relational data model: data is stored in relations
  - Example: Banking Info

Account	Branch	Name	Balance
4500	Pomona	Mary	18,300
6831	Claremont	John	15,000
9834	Pasadena	Erin	11,000

- A declarative query language
  - Specify what answer a query should return, but not how the query is executed
  - Ex. SQL – structured query language
  - Query : What is Mary's balance?

```
SELECT    balance
FROM      Banking
WHERE     name = "Mary" ;
```

Relational Model: Levels of Abstraction

- Conceptual/Logical schema

  Describes the data model

  - Students(***sid:*** string, ***name:*** string, ***login:*** string, ***gpa:*** real)
  - Courses(***cid:*** string, ***cname:*** string, ***credits:*** integer)
  - Enrollment(***sid:*** string, ***cid:*** string, ***grade:*** string)

- Physical schema

  Storage details

  - Store the relations as unsorted files
  - Create indexes on Students.sid and Courses.sid

- External schema ("views")

  Allow Customized data access

  - View each course's enrollment

```
CREAT VIEW  CourseInfo AS
        SELECT cid, COUNT (*) as enrollment
        FROM Enrolled
        GROUP BY cid;
```

  - **CoureInfo** (***cid:*** string, ***enrollment:*** integer)

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ACID Properties

- Atomicity – system should ensure that updates of a partially executed transaction are not reflected in the database.
- Consistency – system should ensure that any changes to values in an instance are consistent with changes to other values in the same instance.
- Durability – system should ensure updates of committed transactions is critical.
- Isolation – system should ensure that transactions that occur in parallel will have same effect if they were run sequentially.

ACID (Cont.) - System Failures

- Banking example … balance transfer
  - Decrement account X by $100
  - Increment account Y by $100

- What if power goes out after first instruction?

  - If first instruction is executed but not the second, then operations are not atomic.

  - DBMS must keep a log of updates, and upon system failure the DBMS will replay the log checking the status of the records to recover database to a consistent state.

ACID (Cont.) - Parallel Transactions

- Transaction 1 – Deposit to account X
- Transaction 2 – Add interest to account X

Transaction 1	Transaction 2
Lookup balance of account X	
	Lookup balance of account X
Deposit 2 times the balance of account x	
	Add 3% to balance of account X

This is an example of lost update…

There are many other scenarios that cause issues when we don't consider the order of transactions running in parallel.

Structured Query Language (SQL)

- SQL was proposed in 1970s by D. Chamberlin and R. Boyce

- Data definition language (DDL)
  - Define the schema (create, change, delete relations)
  - Specify constrains, user permissions
  - Ex. CREATE TABLE Students (sid string, name string, ….);

- Data modification language (DML)
  - Find data that matches criteria
  - Add, remove, update data
  - The DBMS is responsible for efficient evaluation
  - Ex. SELECT * FROM Students were name = “Mary”;

SQL: Creating Relations

- Create Students relation:

```
CREATE TABLE  Students (
        sid CHAR(20),
        name CHAR(20),
        login CHAR(20),
        SSN CHAR(12),
        gpa FLOAT
);
```

- Create Enrolled relation:

```
CREATE TABLE  Enrolled (
        sid CHAR(20),
        cid CHAR(20),
        grade FLOAT
);
```

Insert a single tuple

INSERT INTO Students (sid, name, login, SSN, gpa) VALUES (21, “Mary”, “marys”, “000-00-0000”, 3.4);

Delete tuples that satisfy condition

```
DELETE FROM Students S
WHERE S.name = “Mary”;
```

Integrity Constraints

- Students

SID	Name	Login	SSN	GPA
45	Mary	maryS	000-000-000	3.4
67	John	johnT	000-000-000	3.5
78	Erin	erinK	000-000-000	3.7

Primary Key

- Enrollment

SID	CID	Grade
45	Mary	100
67	John	99
78	Erin	89

Foreign Key

- The Primary Key is a field that uniquely identifies a tuple (a super key is a set of fields)
- A Foreign Key is a key in one relation refers to a primary key of another relation.

SQL: Creating Relations

- Create Students relation:

```
CREATE TABLE  Students (
        sid CHAR(20),
        name CHAR(20),
        login CHAR(20),
        SSN CHAR(12),
        gpa FLOAT
        PRIMARY KEY(sid),
        UNIQUE (SSN)
);
```

- Create Enrolled relation:

```
CREATE TABLE  Enrolled (
        sid CHAR(20),
        cid CHAR(20),
        grade FLOAT,
        PRIMARY KEY (sid,cid),
        FOREIGN KEY (sid)
);
```

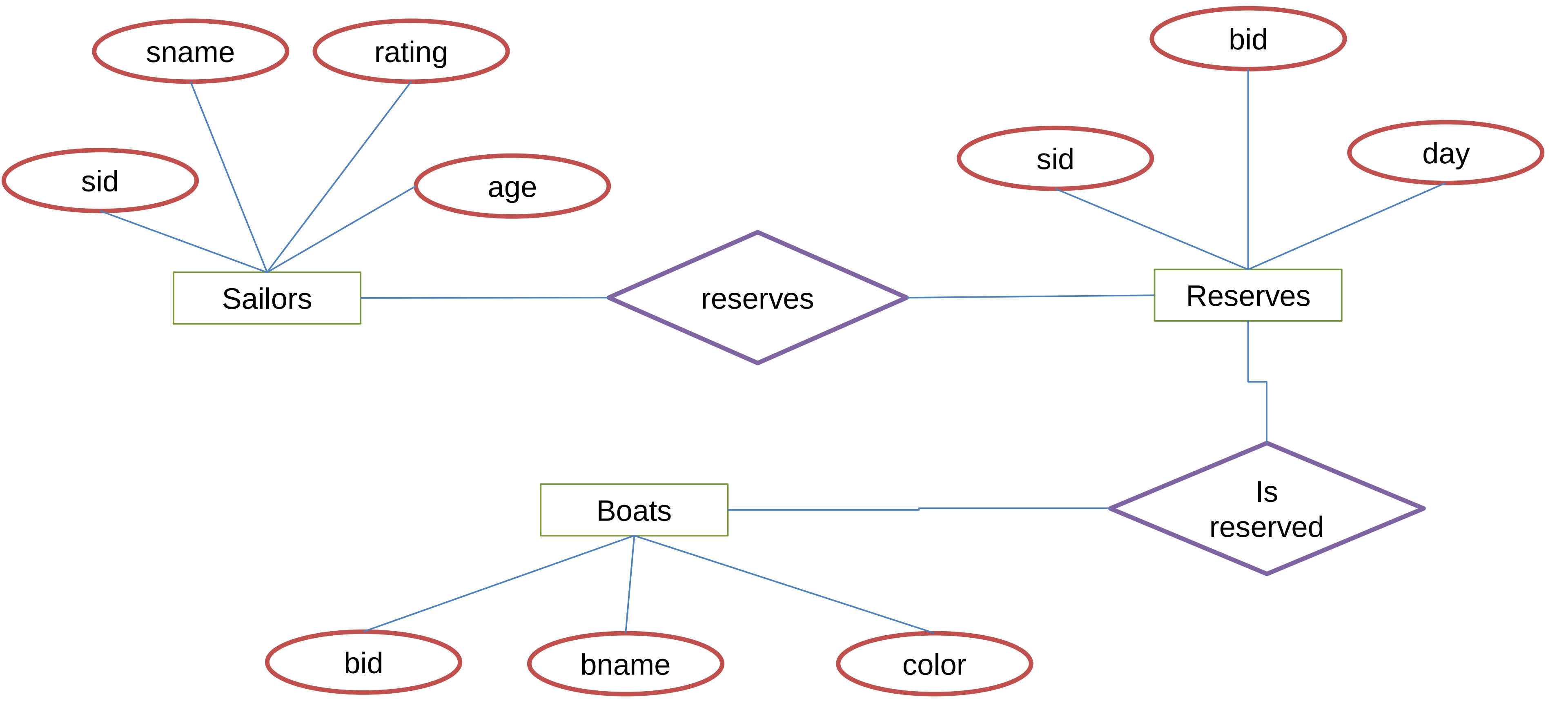
Basic SQL Query

Remove duplicate tuples

Selecting fields of interest →	SELECT	[DISTINCT] target-list
Set of relations →	FROM	relation-list
Discard tuples that fail condition →	WHERE	qualification
Order tuples in result →	ORDER BY	fields(s) [ASC|DESC]
Limit number of tuples in the result →	LIMIT	num_rows

What actually happens when you write a SQL query?? Well, the query is optimized before execution… but we still should try to write efficient queries.

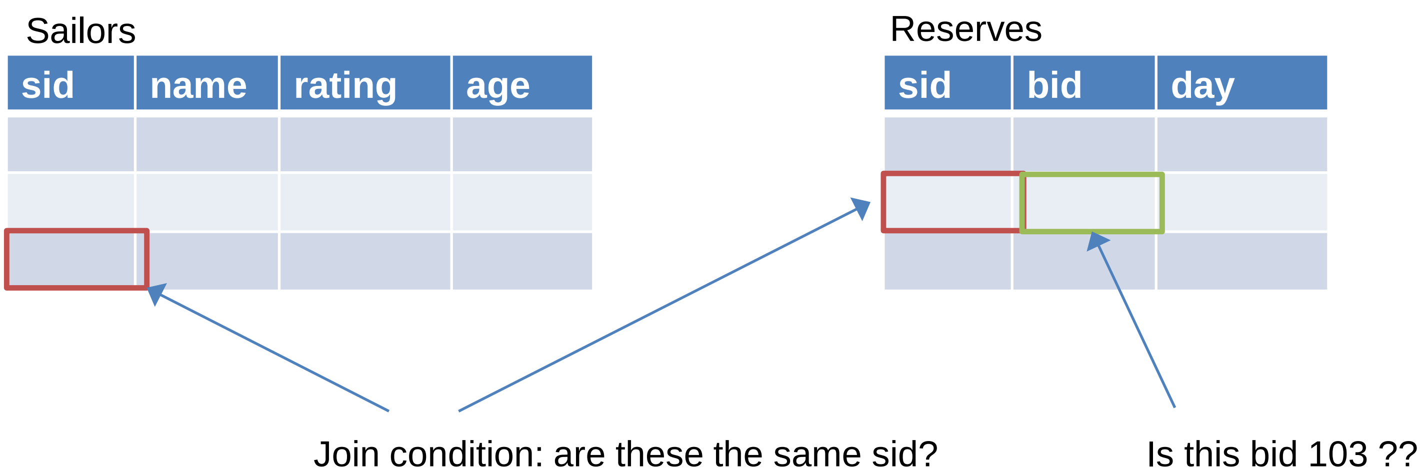
Example



sname
rating
bid
sid
day
sid
age
Sailors
reserves
Reserves
Is
reserved
Boats
bid
bname
color

Visualizing Query Evaluation

SELECT sname
FROM Sailors, Reserves
WHERE Sailors.sid = Reserves.sid AND bid=103



Example Relation Instances

Sailors

Sid v	name	rating	age
22	Dustin	7	45
31	Lubber	8	55.5
95	Bob	3	63.5

Boats

bid	bname	color
101	SinkRise	blue
102	SinkRise	red
103	Clipper	green
104	Marine	red

Reserves

sid	bid	day
22	101	10/10/96
95	103	11/12/96

Range Variables

- We can associate "range variables" with the relations in the FROM clause
  - Saves writing, makes queries easier to understand
  - Like an alias
- Needed when ambiguity could arise
  - For example, if the same relation used multiple times in the same FROM clause (called self-join)

```
SELECT  sname
FROM    Sailors S, Reserves R
WHERE   S.sid = R.sid;
```

QUERY: Find all the Sailors who have reserved at least 1 boat

Range Variables

- Example where range variables are required (self-join example)

```
SELECT    S1.sname, S1.age, S2.name, S2.age
FROM      Sailors S1, Sailors S2
WHERE     S1.age = S2.age  AND
          S1.rating = S2.rating;
```

Since we are doing a self-join, we need to use the “Range Variables”

NULL Values

- Field values in a tuple are sometimes missing
  - Unknown (e.g. a rating or grade has not been assigned)
  - Inapplicable (e.g. no spouse's name)
  - SQL provides a special value null for such situations.

- The presence of null complicates things
  - Is "rating > 8" true or false when rating is null?
  - It is not possible to test for NULL values with comparison operators, such as =, <, or <>.
  - Proper way: check if a value is not null using IS NULL

Lastname	FirstName	Address
Smith	Dustin	
Hansen	Lubber	
Patterson	Bob	

```
SELECT  LastName, FirstName, Address
FROM    Persons
WHERE   Address IS NULL
```

Null Values – 3 Valued Logic

- We need a 3-valued logic:
  - Values : True, False, and Unknown

AND	T	F	NULL
T	T	F	Unknown
F	F	F	F
NULL	Unknown	F	Unknown

OR	T	F	NULL
T	T	T	T
F	T	F	Unknown
NULL	T	Unknown	Unknown

Expressions

- Can use arithmetic expressions in SELECT clause (plus other calculations we'll discuss later)
- Use AS to provide column names

```
SELECT  S.sname, S.rating %2 AS evenOddRating
FROM    Sailors S
WHERE   S.age >= 18;
```

- Can also have expressions in WHERE clause:

```
SELECT  S1.sname as name1, S2.sname as name2
FROM    Sailors S1, Sailors S2
WHERE   2*S1.rating > S2.rating;
```

- **QUERY**: Find sids of sailors who have reserved a red or green boat

```
SELECT    DISTINCT R.sid
FROM      Boats B, Reserves R
WHERE     R.bid = B.bid AND
          B.color='red' AND B.color='green';
```

Is this correct???

- **QUERY**: Find sids of sailors who have reserved a red or green boat

```
SELECT    DISTINCT R.sid
FROM      Boats B, Reserves R
WHERE     R.bid = B.bid AND
          (B.color='red' OR B.color='green');
```

- **UNION:** allows to compute the union of two union-compatible sets of tuples

```
SELECT    DISTINCT R.sid
FROM      Boats B, Reserves R
WHERE     R.bid = B.bid AND B.color='red'
UNION
SELECT    DISTINCT R.sid
FROM      Boats B, Reserves R
WHERE     R.bid = B.bid AND B.color='green';
```

- **QUERY:** Find sids of sailors who have reserved a red and a green boat.

INTERSECT:

- Can be used to compute the intersection of any two union-compatible sets of tuples

INTERSECT will find the overlapping tuples between the first and second queries.

```
SELECT   R.sid
FROM     Boats B, Reserves R
WHERE    R.bid = B.bid AND B.color='red'

INTERSECT

SELECT   R.sid
FROM     Boats B, Reserves R
WHERE    R.bid = B.bid AND B.color='green';
```

Nested Queries

- Can use SQL queries to aid the evaluation of another SQL query
- WHERE clause can itself contain an SQL query~
  - Actually, so can FROM and HAVING clauses.

```
SELECT    S.sid
FROM      Sailors S
WHERE     S.rating > (SELECT AVG(rating)
                      FROM Sailors);
```

To understand semantics of nested queries, think of a nested loops evaluation: For each Sailors tuple, check the qualification by computing the subquery.

Nested Queries

- Subqueries can also be relations with many tuples
- **QUERY**: Find Sailors who have not reserved boat #103

```
SELECT    S.sname
FROM      Sailors S
WHERE     S.sid NOT IN (
              SELECT    R.sid
              FROM      Reserves R
              WHERE     R.bid = 103
          );
```

Nested Queries with Correlation

- **QUERY:** Find names of sailors who've reserved boat #103

  - EXISTS is another set comparison operator, like IN.

```
SELECT    S.sname
FROM      Sailors S
WHERE     EXISTS  (
              SELECT    *
              FROM   Reserves R
              WHERE     R.bid = 103 AND S.sid=R.sid
          );
```

More on Set-Comparison Operators

- We've already seen IN, EXISTS and UNIQUE.
- Can also use NOT IN, NOT EXISTS and NOT UNIQUE.
- Also available: op ANY, op ALL, op IN

- **QUERY:** Find sailors whose rating is greater than that of some sailor called Horatio

```
SELECT  *
FROM   Sailors S
WHERE  S.rating > ANY (
                    SELECT S2.rating
                    FROM Sailors S2
                    WHERE S2.sname='Horatio')
```

Rewriting INTERSECT Queries Using IN

- **QUERY:** Find sid's of sailors who've reserved both a red and a green boat

But why???
INTERSECT is not supported by all databases

```
SELECT   S.sid
FROM     Sailors S, Boats B, Reserves R
WHERE    S.sid=R.sid AND R.bid=B.bid AND B.color='red'
         AND S.sid IN (
                   SELECT   S2.sid
                   FROM     Sailors S2, Boats B2, Reserves R2
                   WHERE    S2.sid=R2.sid AND R2.bid=B2.bid
                    AND B2.color='green')
```

- Similarly, EXCEPT queries can be re-written using NOT IN.

Aggregate Operators

- COUNT (*)
- COUNT ([DISTINCT] A)
- SUM ([DISTINCT] A)
- AVG ([DISTINCT] A)
- MAX (A)
- MIN (A)

```
SELECT AVG ( DISTINCT S.age)
FROM Sailors S
WHERE S.rating=10
```

```
SELECT COUNT (*)
FROM Sailors S
```

```
SELECT AVG (S.age)
FROM Sailors S
WHERE S.rating=10
```

```
SELECT S.sname
FROM Sailors S
WHERE S.rating = (      SELECT MAX(S2.rating)
                        FROM Sailors S2)
```

```
SELECT COUNT (DISTINCT S.rating)
FROM Sailors S
WHERE S.sname=‘Bob’
```

- **QUERY:** Find name and age of the oldest sailor.

```
SELECT S.sname, MAX (S.age)
FROM Sailors S
```

- Does the above query work???

```
SELECT S.sname, S.age
FROM Sailors S
WHERE S.age = (
                SELECT MAX (S2.age)
                FROM Sailors S2 )
```

GROUP BY and HAVING

SELECT [**DISTINCT**] target-list

FROM relation-list

WHERE qualification

GROUP BY grouping-list

HAVING group-qualification

- The target-list contains
  - (i) attribute names
  - (ii) terms with aggregate operations (e.g., MIN (S.age)).
- The attribute list (i) must be a subset of grouping-list.
- Intuitively, each answer tuple corresponds to a group, and these attributes must have a single value per group. (A group is a set of tuples that have the same value for all attributes in grouping-list.)

Evaluations of GROUP BY

- The cross-product of relation-list is computed, tuples that fail qualification are discarded, `unnecessary' fields are deleted, and the remaining tuples are partitioned into groups by the value of attributes in grouping-list.

- The group-qualification is then applied to eliminate some groups.

- Expressions in group-qualification must have a single value per group! In effect, an attribute in group-qualification that is not an argument of an aggregate op also appears in grouping-list. (SQL does not exploit primary key semantics here!)

- One answer tuple is generated per qualifying group.

- **QUERY:** Find the age of the youngest sailor with age 18, for each rating with at least 2 such sailors

```
SELECT    S.rating, MIN (S.age)
FROM      Sailors S
WHERE     S.age >= 18
GROUP BY  S.rating
HAVING COUNT (*) > 1
```

Only S.rating and S.age are mentioned in the SELECT, GROUP BY or HAVING clauses; other attributes `unnecessary'.

2nd column of result is unnamed. (Use AS to name it.)

Sailors

sid	name	rating	age
22	Dustin	7	45
31	Lubber	8	55.5
64	Rusty	3	18
45	Chris	5	20
37	Brian	4	17
95	Bob	3	63.5

→

rating	age
7	45
8	55.5
3	18
5	20
4	17
3	63.5

→

rating	age
7	45
8	55.5
3	18
5	20
3	63.5

→

rating	age
3	18
3	63.5

→

rating	
3	18