SQL

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Topic 5: SQL, An Implementation of The RA

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SQL

Development of Relational Database Systems

- Relation Model and Algebra proposed by C.J.Codd in 1970
- IBM developed a prototype relational database called **System R** with a query language **Structured English Query Language** (**SEQUEL**)
- SEQUEL later renamed **SQL**
- Various commercial versions of SQL launched in late 1970's/early 1980s
  - **DB2**
  - **Oracle**
  - **Sybase**

  ...

SQL Language Components

Data Definition Language (**DDL**): a relational schema with data
Data Manipulation Language (**DML**): a relational query and update language

SQL DDL: Definition of Tables

```
CREATE TABLE branch
(   sortcode INTEGER NOT NULL,
    bname VARCHAR(20) NOT NULL,
    cash DECIMAL(10,2) NOT NULL
)
```

branch		
sortcode	bname	cash

```
CREATE TABLE account
(   no INTEGER NOT NULL,
    type VARCHAR(8) NOT NULL,
    cname VARCHAR(20) NOT NULL,
    rate DECIMAL(4,2) NULL,
    sortcode INTEGER NOT NULL
)
```

account				
no	type	cname	rate?	sortcode

SQL DDL: SQL Data Types

Some SQL Data Types	
Keyword	Semantics
BOOLEAN	A logical value (TRUE, FALSE, or UNKNOWN)
BIT	1 bit integer (0, 1, or NULL)
SMALLINT	16 bit integer
INTEGER	32 bit integer
BIGINT	64 bit integer
FLOAT(n)	An n bit mantissa floating point number
REAL	32 bit floating point number ($\equiv$ FLOAT(24))
DOUBLE PRECISION	64 bit floating point number ($\equiv$ FLOAT(53))
DECIMAL(p,s)	A p digit number with s digits after the decimal point
CHAR(n)	A fixed length string of n characters
VARCHAR(n)	A varying length string of upto n characters
DATE	A calendar date (day, month and year)
TIME	A time of day (seconds, minutes, hours)
TIMESTAMP	time and day together
ARRAY	An ordered list of a certain datatype
MULTISET	A bag (*i.e.* unordered list) of a certain datatype
XML	XML text

SQL DDL: Definition of Keys

```
CREATE TABLE branch
(   sortcode INTEGER NOT NULL,
    bname VARCHAR(20) NOT NULL,
    cash DECIMAL(10,2) NOT NULL,
    CONSTRAINT branch_pk PRIMARY KEY (sortcode)
)
```

branch		
<u>sortcode</u>	bname	cash

```
CREATE TABLE account
(   no INTEGER NOT NULL,
    type VARCHAR(8) NOT NULL,
    cname VARCHAR(20) NOT NULL,
    rate DECIMAL(4,2) NULL,
    sortcode INTEGER NOT NULL,
    CONSTRAINT account_pk PRIMARY KEY (no),
    CONSTRAINT account_fk FOREIGN KEY (sortcode)
    REFERENCES branch
)
```

account				
<u>no</u>	type	cname	rate	sortcode

account(sortcode) $\stackrel{fk}{\Rightarrow}$ branch(sortcode)

Keys and the Primary Key

Keys

The alternative keys of a table are called **candidate keys**

Primary Key

- Choose the key most often used to access a table as the **primary key**
- Has no logical impact on the relational model
- Has an operation impact: index created that accesses the data faster
- All other keys are called **secondary keys**

Declaring Primary Keys after table creation

```
ALTER TABLE branch
ADD CONSTRAINT branch_pk PRIMARY KEY (sortcode);
```

Declaring Secondary Keys for a table

```
CREATE UNIQUE INDEX branch_bname_key ON branch(bname)
```

SQL DML: Inserting, Updating and Deleting Data

```
INSERT INTO account
VALUES (100,'current','McBrien, P.',NULL,67),
(101,'deposit','McBrien, P.',5.25,67),
(103,'current','Boyd, M.',NULL,34),
(107,'current','Poulovassilis, A.',NULL,56),
(119,'deposit','Poulovassilis, A.',5.50,56),
(125,'current','Bailey, J.',NULL,56)
```

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

```
UPDATE account
SET    type='deposit'
WHERE  no=100
```

account

no	type	cname	rate	sortcode
100	'deposit'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

```
DELETE
FROM   account
WHERE  no=100
```

account

no	type	cname	rate	sortcode
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

SQL DML: An Implementation of the RA

SQL SELECT statements: Rough Equivalence to RA

$$\begin{array}{ll} \text{SELECT} & A_1, \ldots, A_n \\ \text{FROM} & R_1, \ldots, R_m \\ \text{WHERE} & P_1 \\ \text{AND} & \ldots \\ \text{AND} & P_k \end{array} \quad \Leftrightarrow \quad \pi_{A_1,\ldots,A_n} \sigma_{P_1 \wedge \ldots \wedge P_k} (R_1 \times \ldots \times R_m)$$

SQL SELECT implements RA π, σ and $\times$

$\pi_{\text{bname,no}}\, \sigma_{\text{branch.sortcode=account.sortcode} \wedge \text{account.type='current'}}\, (\text{branch} \times \text{account})$

```
SELECT  branch.bname,
        account.no
FROM    account, branch
WHERE   account.sortcode=
                branch.sortcode
AND     account.type='current'
```

bname	no
Strand	100
Goodge St	103
Wimbledon	107
Wimbledon	125

SQL DML: An Implementation of the RA

SQL SELECT statements: Rough Equivalence to RA

$$\begin{array}{ll} \text{SELECT} & A_1, \ldots, A_n \\ \text{FROM} & R_1, \ldots, R_m \\ \text{WHERE} & P_1 \\ \text{AND} & \ldots \\ \text{AND} & P_k \end{array} \quad \Leftrightarrow \quad \pi_{A_1,\ldots,A_n} \sigma_{P_1 \wedge \ldots \wedge P_k} (R_1 \times \ldots \times R_m)$$

SQL SELECT implements RA π, σ and $\times$

$\pi_{\text{bname,no}}\, \sigma_{\text{branch.sortcode=account.sortcode} \wedge \text{account.type='current'}}\, (\text{branch} \times \text{account})$

```
SELECT  branch.bname,
        account.no
FROM    account
        JOIN branch
        ON   account.sortcode=
               branch.sortcode
WHERE   account.type='current'
```

bname	no
Strand	100
Goodge St	103
Wimbledon	107
Wimbledon	125

Naming columns in SQL

Column naming rules in SQL

- You must never have an ambiguous column name in an SQL statement
- You can use SELECT * to indicate all columns (*i.e.* have no projection)
- You can use tablename.* to imply all columns from a table

✓

```
SELECT  branch.bname,
        account.sortcode
FROM    account JOIN branch
        ON account.sortcode=
             branch.sortcode
WHERE   account.type='current'
```

✗

```
SELECT  bname,
        sortcode
FROM    account JOIN branch
        ON account.sortcode=
             branch.sortcode
WHERE   type='current'
```

✓

```
SELECT  bname,
        account.sortcode
FROM    account JOIN branch
        ON account.sortcode=
             branch.sortcode
WHERE   type='current'
```

✓

```
SELECT  branch.*,
        no
FROM    account JOIN branch
        ON account.sortcode=
             branch.sortcode
WHERE   type='current'
```

sortcode	bname	cash	no
67	'Strand'	34005.00	100
34	'Goodge St'	8900.67	103
56	'Wimbledon'	94340.45	107
56	'Wimbledon'	94340.45	125

Quiz 5.1: Translating RA into SQL

Which SQL query implements $\pi_{\text{bname,no}}\,\sigma_{\text{type='deposit'}}(\text{account} \bowtie \text{branch})$?

A

```
SELECT  *
FROM    account , branch
WHERE   type='deposit'
```

B

```
SELECT  bname , no
FROM    account , branch
WHERE   type='deposit'
```

C

```
SELECT  bname , no
FROM    branch , account
WHERE   branch . sortcode=
            account . sortcode
AND     type='deposit'
```

D

```
SELECT  bname , no
FROM    account , branch
WHERE   branch . sortcode=
            account . no
AND     type='deposit'
```

Connectives Between SQL SELECT statements

Binary operators between SELECT statements

- SQL UNION implements RA $\cup$
- SQL EXCEPT implements RA $-$
- SQL INTERSECT implements RA $\cap$

Note that two tables must be **union compatible**: have the same number and type of columns

π_{no}account $-$ π_{no}movement

```
SELECT no
FROM   account
EXCEPT
SELECT no
FROM   movement
```

SQL NATURAL JOIN

Natural join performs a join on the attributes that appear in both relations, and returns each attribute once

e.g. branch ⋈ account joins on sortcode

Best to use JOIN ... ON or USING

SQL JOIN ... ON

```
SELECT branch.*, no, type, cname, rate
FROM   branch JOIN account
       ON branch.sortcode=account.sortcode
```

Classic SQL

```
SELECT branch.*, no, type, cname, rate
FROM   branch, account
WHERE  branch.sortcode=account.sortcode
```

SQL NATURAL JOIN

```
SELECT *
FROM   branch NATURAL JOIN
       account
```

sortcode	bname	cash	no	type	cname	rate
67	Strand	34005.00	100	current	McBrien, P.	null
67	Strand	34005.00	101	deposit	McBrien, P.	5.25
34	Goodge St	8900.67	103	current	Boyd, M.	null
56	Wimbledon	94340.45	107	current	Poulovassilis, A.	null
56	Wimbledon	94340.45	119	deposit	Poulovassilis, A.	5.50
56	Wimbledon	94340.45	125	current	Bailey, J.	null

SQL JOIN ... USING

```
SELECT branch.*, no, type, cname, rate
FROM   branch JOIN account
       USING (sortcode)
```

SQL CROSS JOIN

```
SELECT branch.*, no, type, cname, rate
FROM   branch CROSS JOIN account
WHERE  branch.sortcode=account.sortcode
```

Overview of RA and SQL correspondances

RA and SQL	
RA Operator	SQL Operator
π	SELECT
σ	WHERE
$R_1 \times R_2$	FROM R_1, R_2 *or* FROM R_1 CROSS JOIN R_2
$R_1 \bowtie R_2$	FROM R_1 NATURAL JOIN R_2
$R_1 \overset{\theta}{\bowtie} R_2$	FROM R_1 JOIN R_2 ON θ
$R_1 - R_2$	R_1 EXCEPT R_2
$R_1 \cup R_2$	R_1 UNION R_2
$R_1 \cap R_2$	R_1 INTERSECT R_2

Table and Column Aliases: AS

AS

```
SELECT  current_account.cname,
        current_account.no AS current_no,
        deposit_account.no AS deposit_no
FROM    account AS current_account
        JOIN account AS deposit_account
        ON    current_account.cname=
                  deposit_account.cname
        AND   current_account.type='current'
        AND   deposit_account.type='deposit'
```

e can b

compa

other

n'

cname	current_no	deposit_no
McBrien, P.	100	101
Poulovassilis, A.	107	119

Table and Column Aliases: AS

```
SELECT  current_account.cname,
        current_account.no AS current_no,
        deposit_account.no AS deposit_no
FROM    account AS current_account
        JOIN account AS deposit_account
        ON    current_account.cname=
                  deposit_account.cname
        AND   current_account.type='current'
        AND   deposit_account.type='deposit'
```

cname	current_no	deposit_no
McBrien, P.	100	101
Poulovassilis, A.	107	119

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

AS current_account

AS deposit_account

current_account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

deposit_account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

Set or Bag Based Semantics: No Iteration

SQL allows either set (DISTINCT) or bag (ALL) based semantics

- Lack of procedural semantics means all queries can execute in parallel
- Might need to think about 'programming' in different ways

Generating 0..999

Table of Constants

```
SELECT hundred.digit*100+ten.digit*10+unit.digit AS n
FROM   (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS unit(digit)
       CROSS JOIN (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS ten(digit)
       CROSS JOIN (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS hundred(digit)
ORDER BY n
```

digit
7
8
9

n	n	n	n		n	n
0	10	20	30		980	990
1	11	21	31		981	991
2	12	22	32		982	992
3	13	23	33		983	993
4	14	24	34	...	984	994
5	15	25	35		985	995
6	16	26	36		986	996
7	17	27	37		987	997
8	18	28	38		988	998
9	19	29	39		989	999

Common Table Expressions: SQL WITH

```
SELECT hundred.digit*100+ten.digit*10+unit.digit AS n
FROM   (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS unit(digit)
       CROSS JOIN (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS ten(digit)
       CROSS JOIN (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9)) AS hundred(digit)
```

```
WITH   decimal(digit) AS (VALUES (0),(1),(2),(3),(4),(5),(6),(7),(8),(9))
SELECT hundred.digit*100+ten.digit*10+unit.digit AS n
FROM   decimal AS unit
       CROSS JOIN decimal AS ten
       CROSS JOIN decimal AS hundred
```

n	n	n	n		n	n
0	10	20	30		980	990
1	11	21	31		981	991
2	12	22	32		982	992
3	13	23	33		983	993
4	14	24	34	...	984	994
5	15	25	35		985	995
6	16	26	36		986	996
7	17	27	37		987	997
8	18	28	38		988	998
9	19	29	39		989	999

A **Common Table Expression** (**CTE**) may define a table that is used in one query

WITH table AS def SELECT ...

Use to avoid repeating definitions

Topic 6: SQL Bags and Sets

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SQL: Bags and Sets

```
SELECT ALL sortcode
FROM   account
```

$\approx \pi_{\text{sortcode}}$ account
sortcode
67
67
56
56
56
34

```
SELECT DISTINCT sortcode
FROM   account
```

π_{sortcode} account
sortcode
34
56
67

SQL SELECT: Bag semantics

- By default, an SQL SELECT (equivalent to an RA π) does *not* eliminate duplicates, and returns a **bag** (or **multiset**) rather than a set.
- Any SELECT that does not cover a key of the input relation, and requires a set based answer, should use DISTINCT.

Quiz 6.1: Correct use of SELECT DISTINCT (1)

branch(sortcode,bname,cash)
key branch(sortcode)
key branch(bname)

Which SQL query requires the use of DISTINCT in order to avoid the possibility of a bag being produced?

A

```
SELECT *
FROM   branch
WHERE  cash >10000
```

B

```
SELECT sortcode
FROM   branch
WHERE  cash >10000
```

C

```
SELECT bname, cash
FROM   branch
```

D

```
SELECT cash
FROM   branch
WHERE  cash >10000
```

Quiz 6.2: Correct use of SELECT DISTINCT (2)

branch(sortcode,bname,cash)
account(no,type,cname,rate,sortcode)

key branch(sortcode)
key branch(bname)
key account(no)

Which SQL query requires the use of DISTINCT in order to avoid the possibility of a bag being produced?

A

```
SELECT *
FROM   branch NATURAL JOIN
       account
```

B

```
SELECT branch.sortcode, type, rate
FROM   branch NATURAL JOIN
       account
```

C

```
SELECT branch.sortcode, no
FROM   branch NATURAL JOIN
       account
```

D

```
SELECT branch.sortcode, no, cash
FROM   branch NATURAL JOIN
       account
```

Quiz 6.3: Operators that might produce bags

If R and S are sets, which RA operator could produce a bag result if the implementation did not check for duplicates?

A	B	C	D
σR	$R \cup S$	$R - S$	$R \times S$

Bag and Set operations in SQL

RA Operator	Set Based SQL	Bag Based SQL
$\pi_{A_1,\ldots,A_n}$	SELECT DISTINCT $A_1, \ldots, A_n$	SELECT ALL $A_1, \ldots, A_n$
$R_1 \times \ldots \times R_m$	FROM $R_1, \ldots, R_m$	FROM $R_1, \ldots, R_m$
$\sigma_{P_1,\ldots,P_k}$	WHERE P_1 AND $\ldots$ AND P_k	WHERE P_1 AND $\ldots$ AND P_k
$R_1 \cup R_2$	R_1 UNION DISTINCT R_2	R_1 UNION ALL R_2
$R_1 - R_2$	R_1 EXCEPT DISTINCT R_2	R_1 EXCEPT ALL R_2
$R_1 \cap R_2$	R_1 INTERSECT DISTINCT R_2	R_1 INTERSECT ALL R_2

Chosing between set and bag semantics

If you omit DISTINCT or ALL, then the defaults are:
SELECT ALL
UNION DISTINCT
EXCEPT DISTINCT
INTERSECT DISTINCT

No FROM DISTINCT or WHERE DISTINCT?

There is no need for DISTINCT or ALL around FROM ($\times$) and WHERE (σ) cannot introduce any duplicates, and any existing duplicates can be removed in the SELECT

Project-Select-Product Queries

SQL SELECT statements: Exact Equivalence to RA

$$\begin{array}{ll} \text{SELECT} & \text{DISTINCT } A_1, ..., A_n \\ \text{FROM} & R_1, ..., R_m \\ \text{WHERE} & P_1 \\ \text{AND} & ... \\ \text{AND} & P_k \end{array} \equiv \pi_{A_1,...,A_n} \sigma_{P_1 \wedge ... \wedge P_k} (R_1 \times \ldots \times R_m)$$

- SQL SELECT implements RA π, σ and $\times$
- Omit DISTINCT when either
  - you known $A_1, ..., A_n$ cover a key
  - you want a bag (rather than set) answer

Quiz 6.4: SQL EXCEPT

```
SELECT  no
FROM    movement
EXCEPT
SELECT  no
FROM    account
```

movement

mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

no
100
101
103
107
119
125

B

no
100
101
103
107
119

C

no
100
100
101
107

D

no

Quiz 6.5: SQL EXCEPT ALL

```
SELECT  no
FROM    movement
EXCEPT  ALL
SELECT  no
FROM    account
```

movement

mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

no
100
101
103
107
119
125

B

no
100
101
103
107
119

C

no
100
100
101
107

D

no

Worksheet: Translating Between Relational Algebra and SQL

account				
no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

movement			
mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

movement(no) $\stackrel{fk}{\Rightarrow}$ account.no

Topic 7: Experiment with SQL in DoC

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Try some examples yourself ...

```
medusa-s2(pjm)-4$ psql -h db -U lab -d bank_branch -W
Password:
bank_branch=> SELECT *
bank_branch-> FROM branch NATURAL JOIN account;
```

sortcode	bname	cash	no	type	cname	rate
67	Strand	34005.00	100	current	McBrien, P.	
67	Strand	34005.00	101	deposit	McBrien, P.	5.25
34	Goodge St	8900.67	103	current	Boyd, M.	
56	Wimbledon	94340.45	107	current	Poulovassilis, A.	
56	Wimbledon	94340.45	119	deposit	Poulovassilis, A.	5.50
56	Wimbledon	94340.45	125	current	Bailey, J.	

Try changing some examples . . .

```
SELECT  bname,
        sortcode
FROM    account,branch
WHERE   account.sortcode=
            branch.sortcode
AND     type='current'

SELECT  bname,
        sortcode
FROM    account
        NATURAL JOIN branch
WHERE   type='current'
```

Topic 8: SQL Set Operations

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Set Operations: IN

IN operator tests for membership of a set

```
SELECT *
FROM   account
WHERE  type='current'
AND    no IN (100,101)
```

Can use nested SELECT to generate set

```
SELECT no
FROM   account
WHERE  type='current'
AND    no IN (SELECT no
              FROM   movement
              WHERE  amount>500)
```

≡

```
SELECT DISTINCT account.no
FROM   account JOIN movement
       ON account.no=movement.no
WHERE  type='current'
AND    amount>500
```

Quiz 8.1: SQL Set Membership Testing

```
SELECT no
FROM   account
WHERE  type='current'
AND    no NOT IN
       ( SELECT no
         FROM   movement
         WHERE  amount>500)
```

≠

```
SELECT DISTINCT account.no
FROM   account
       JOIN movement
       ON account.no=movement.no
WHERE  type='current'
AND    NOT amount>500
```

(Gives answer B)

What is the result of the above SQL query?

A

no
100
103
107
125

B

no
100
103
107

C

no
103
107
125

D

no
103
107

Set Operations: EXISTS

Testing for Existence

- IN can be used to test if some value is in a relation, either listed, or produced by some SELECT statement
- EXISTS can be used to test if a SELECT statement returns any rows

List people without a deposit account

```
SELECT DISTINCT cname
FROM   account
WHERE  cname NOT IN
( SELECT cname
  FROM   account
  WHERE  type='deposit')
```

≡

```
SELECT DISTINCT cname
FROM   account
WHERE NOT EXISTS
    (SELECT cname
     FROM   account AS deposit_account
     WHERE  type='deposit'
     AND    account.cname=deposit_account.cname)
```

cname
'Boyd, M.'
'Bailey, J.'

≡

```
SELECT DISTINCT cname
FROM   account
WHERE NOT EXISTS
    (SELECT *
     FROM   account AS deposit_account
     WHERE  type='deposit'
     AND    account.cname=cname)
```

SQL Correlated Subquery

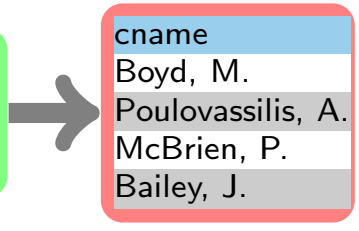
A subquery that references the outer query columns is called a **correlated subquery**

Semantics is as if the subquery is executed for each row of the outer query WHERE clause

```
SELECT DISTINCT cname
FROM   account
WHERE  NOT EXISTS
           (SELECT *
            FROM   account AS deposit_account
            WHERE  type='deposit'
            AND    account.cname=cname)
```

Outer Query: Finds All Names

```
SELECT DISTINCT cname
FROM   account
```



cname
Boyd, M.
Poulovassilis, A.
McBrien, P.
Bailey, J.

Subquery Execution for 'Boyd.M.'

'Boyd.M.'=deposit_acccount.cname
NOT EXISTS succeeds

```
SELECT cname
FROM   account AS deposit_account
WHERE  type='deposit'
AND    'Boyd, M.'=deposit_account.cname
```

cname

SQL Correlated Subquery

A subquery that references the outer query columns is called a **correlated subquery**

Semantics is as if the subquery is executed for each row of the outer query WHERE clause

```
SELECT DISTINCT cname
FROM   account
WHERE  NOT EXISTS
           (SELECT *
            FROM   account AS deposit_account
            WHERE  type='deposit'
            AND    account.cname=cname)
```

Subquery Execution for ' Poulovassilis , A.'

```
SELECT cname
FROM   account AS deposit_account
WHERE  type='deposit'
AND    'Poulovassilis , A.'=deposit_account.cname
```

' Poulovassilis , A.'=
deposit_acccount.cname
NOT EXISTS fails

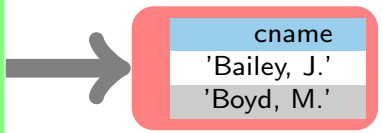
cname
Poulovassilis, A.

SQL Correlated Subquery

A subquery that references the outer query columns is called a **correlated subquery**

Semantics is as if the subquery is executed for each row of the outer query WHERE clause

```
SELECT DISTINCT cname
FROM   account
WHERE  NOT EXISTS
           (SELECT *
            FROM   account AS deposit_account
            WHERE  type='deposit'
            AND    account.cname=cname)
```



cname
'Bailey, J.'
'Boyd, M.'

Complete result

Set Operations: EXISTS

NOT EXISTS and EXCEPT

- Most queries involving EXCEPT can be also written using NOT EXISTS
- EXCEPT relatively recent addition to SQL

π_{no}account − π_{no}movement

```
SELECT no                    SELECT no
FROM   account               FROM   account
EXCEPT                  ≡    WHERE  NOT EXISTS (SELECT no
SELECT no                                       FROM   movement
FROM   movement                                 WHERE  no=account.no)
```

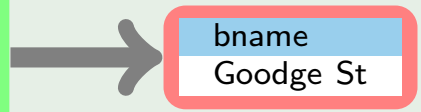
Set Operations: SOME and ALL

Can test a value against members of a set

- V op SOME S is TRUE is there is at least one $V_s \in S$ such that V op V_s
- V op ALL S is TRUE is there are no values $V_s \in S$ such that NOT V op V_s

names of branches that only have current accounts

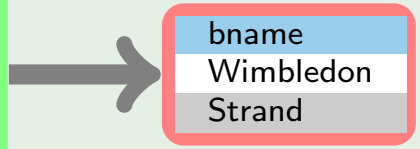
```
SELECT bname
FROM   branch
WHERE  'current'=ALL (SELECT type
                      FROM   account
                      WHERE  branch.sortcode=account.sortcode)
```



bname
Goodge St

names of branches that have deposit accounts

```
SELECT bname
FROM   branch
WHERE  'deposit'=SOME (SELECT type
                       FROM   account
                       WHERE  branch.sortcode=account.sortcode)
```



bname
Wimbledon
Strand

Worksheet: Set Operations

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

movement			
mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

account				
no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

key branch(sortcode)

key branch(bname)

key movement(mid)

key account(no)

movement(no) $\stackrel{fk}{\Rightarrow}$ account(no)

account(sortcode) $\stackrel{fk}{\Rightarrow}$ branch(sortcode)

Worksheet: Set Operations (3)

Write an SQL query without using any negation (*i.e.* without the use of NOT or EXCEPT) that list accounts with no movements on or before the 11-Jan-1999.

```
SELECT no
FROM   account
WHERE  '11-jan-1999'<ALL (SELECT tdate
                          FROM   movement
                          WHERE  movement.no=account.no)
```

Worksheet: Set Operations (4)

Write an SQL query that lists the cname of customers that have every type of account that appears in account

```
SELECT DISTINCT cname
FROM   account AS cust_account
WHERE  NOT EXISTS ( SELECT type
                    FROM   account
                    EXCEPT
                    SELECT type
                    FROM   account
                    WHERE  account.cname=cust_account.cname
                  )
```

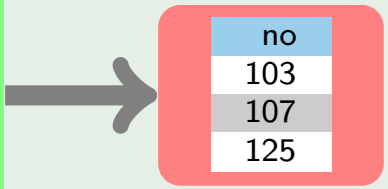
Set Operations: NOT SOME NOT and ALL

Equivalence between *exists* and *for all*

In first order classical logic $\neg\exists\neg \equiv \forall$

accounts with all movements less than or equal to 500

```
SELECT no
FROM   account
WHERE  500>=ALL (SELECT amount
                 FROM   movement
                 WHERE  account.no=movement.no)
```



no
103
107
125

$\equiv$

```
SELECT no
FROM   account
WHERE  NOT 500<SOME (SELECT amount
                     FROM   movement
                     WHERE  account.no=movement.no)
```

Topic 9: SQL Null Values

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Null

Several definitions of null have been proposed, including:

1. null represents a something that is not present in the UoD
2. null represents something that might be present in the UoD, but we do not know its value at present
3. null represents something that is present in the UoD, but we do not know its value at present

SQL handling of NULL

- SQL standard vague, but handling of NULL is nearest to option 2
- SQL uses a three valued logic to process WHERE predicate
- Truth values are TRUE, FALSE, and UNKNOWN

Quiz 9.1: SQL handling of NULL (1)

account				
no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

```
SELECT  no
FROM    account
WHERE   rate=NULL
```

What is the result of the SQL query above?

A

no
100
101
103
107
119
125

B

no
100
103
107
125

C

no
101
119

D

no

Quiz 9.2: SQL handling of NULL (2)

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

```
SELECT  no
FROM    account
WHERE   rate=NULL
OR      rate<>NULL
```

What is the result of the SQL query above?

A

no
100
101
103
107
119
125

B

no
100
103
107
125

C

no
101
119

D

no

SQL implements three valued logic

AND

P_1 AND P_2		P_2		
		TRUE	UNKNOWN	FALSE
P_1	TRUE	TRUE	UNKNOWN	FALSE
	UNKNOWN	UNKNOWN	UNKNOWN	FALSE
	FALSE	FALSE	FALSE	FALSE

OR

P_1 OR P_2		P_2		
		TRUE	UNKNOWN	FALSE
P_1	TRUE	TRUE	TRUE	TRUE
	UNKNOWN	TRUE	UNKNOWN	UNKNOWN
	FALSE	TRUE	UNKNOWN	FALSE

NOT

		NOT P_1
P_1	TRUE	FALSE
	UNKNOWN	UNKNOWN
	FALSE	TRUE

Truth values of SQL Formulae

Formula	Result
x=NULL	UNKNOWN
NULL=NULL	UNKNOWN
x IS NULL	TRUE if x has a null value, FALSE otherwise
x IS NOT NULL	TRUE if x does not have a null value, FALSE otherwise

Quiz 9.3: Possible answers to queries using NULL

```
SELECT  name
FROM    message
WHERE   name=NULL
```

Suppose you have just connected to some database called enigma. Which of the following would not be a possible result of executing the query above?

A

name

B

name
NULL

C

Table **message** does not exist

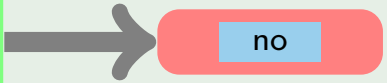
D

No column **name** found in table **message**

'Correct' SQL Queries Using NULL

A query that always returns no rows

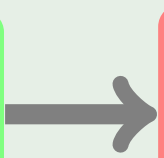
```
SELECT no
FROM   account
WHERE  rate=NULL
```



no

Find all accounts with no interest rate set

```
SELECT no
FROM   account
WHERE  rate IS NULL
```



no
100
103
107
125

Find accounts with a interest rate not equal to 5.5 or not set

```
SELECT no
FROM account
WHERE (rate=5.50) IS NOT TRUE
```

no
100
101
103
107
125

Quiz 9.4: SQL 'Might Be'

```
SELECT no
FROM   account
WHERE  (rate=5.25) IS NOT FALSE
```

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

no
100
101
103
107
125

B

no
100
103
107
119
125

C

no
100
103
107
125

D

no

Worksheet: NULL values in SQL

movement			
mid	no?	amount?	tdate?
0999	119	45.00	null
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999
1010	100	null	20/1/1999
1011	null	null	20/1/1999
1012	null	600.00	20/1/1999
1013	null	-46.00	20/1/1999

account				
no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	null	67
101	'deposit'	'McBrien, P.'	5.25	67
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	null	56

Quiz 9.5: SQL EXCEPT and NULL

```
SELECT  rate
FROM    account
WHERE   no<105
EXCEPT
SELECT  rate
FROM    account
WHERE   sortcode=56
```

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

rate

B

rate
5.25

C

rate
5.25
NULL

D

rate
5.25
NULL
NULL

Equivalences Between EXCEPT, NOT IN and NOT EXISTS

R(A) and S(B), A and B are not nullable

```
SELECT A
FROM   R
EXCEPT
SELECT B
FROM   S
```

≡

```
SELECT A
FROM   R
WHERE  NOT EXISTS
       (SELECT *
        FROM   S
        WHERE  S.B=R.A)
```

≡

```
SELECT A
FROM   R
WHERE  A NOT IN
       (SELECT B
        FROM   S)
```

R(A) and S(B), A or B are nullable

```
SELECT A
FROM   R
EXCEPT
SELECT B
FROM   S
```

≢

```
SELECT A
FROM   R
WHERE  NOT EXISTS
       (SELECT *
        FROM   S
        WHERE  S.B=R.A)
```

≢

```
SELECT A
FROM   R
WHERE  A NOT IN
       (SELECT B
        FROM   S)
```

Quiz 9.6: SQL EXCEPT and NOT IN

```
SELECT  rate
FROM    account
WHERE   no<105
AND     rate  NOT  IN
              (SELECT  rate
               FROM    account
               WHERE   sortcode=56)
```

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

rate

B

rate
5.25

C

rate
5.25
NULL

D

rate
5.25
NULL
NULL

Quiz 9.7: SQL EXCEPT and NOT EXISTS

```
SELECT  rate
FROM    account
WHERE   no<105
AND     NOT EXISTS
        (SELECT *
         FROM   account AS account_56
         WHERE  sortcode=56
         AND    account_56.rate=account.rate)
```

account

no	type	cname	rate?	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

What is the result of the above SQL query?

A

rate

B

rate
5.25

C

rate
5.25
NULL

D

rate
5.25
NULL
NULL