SQL: A Language for Database Applications

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Bank Branch Database

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)

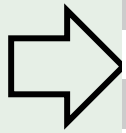
Processing the result of project: CASE statements

CASE statements

A CASE statement may be put in the SELECT clause to process the values being returned.

Display account interest rates

```
SELECT  no,
        COALESCE(rate,0.00) AS rate,
        CASE
        WHEN rate>0 AND rate<5.5
        THEN 'low rate'
        WHEN rate>=5.5
        THEN 'high rate'
        ELSE 'zero rate'
        END AS interest_class
FROM    account
```



no	rate	interest_class
100	0.00	zero rate
101	5.25	low rate
103	0.00	zero rate
107	0.00	zero rate
119	5.50	high rate
125	0.00	zero rate

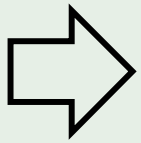
Need for yet another type of Join?

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

Listing of movement mid for all customers with movements

```
SELECT cname,
       mid
FROM   account NATURAL JOIN
       movement
```



cname	mid
McBrien, P.	1000
McBrien, P.	1001
McBrien, P.	1002
Poulovassilis, A.	1004
Boyd, M.	1005
McBrien, P.	1006
Poulovassilis, A.	1007
McBrien, P.	1008
Poulovassilis, A.	1009

Left and Right Joins

Left Join

A left join $R \overset{\text{L}}{\bowtie} S$ returns every row in R, even if no rows in S match. In such cases where no row in S matches a row from R, the columns of S are filled with NULL values.

Right Join

A right join $R \overset{\text{R}}{\bowtie} S$ returns every row in S, even if no rows in R match. In such cases where no row in R matches a row from S, the columns of R are filled with NULL values.

Outer Join

An outer join $R \overset{\text{O}}{\bowtie} S$ returns every row in R, even if no rows in S match, and also returns every row in S even if no row in R matches.

$$R \overset{\text{O}}{\bowtie} S \equiv (R \overset{\text{L}}{\bowtie} S) \cup (R \overset{\text{R}}{\bowtie} S)$$

Need for yet another type of Join?

account

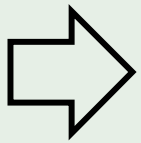
no	type	cname	rate	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
103	'current'	'Boyd, M.'	NULL	34
107	'current'	'Poulovassilis, A.'	NULL	56
119	'deposit'	'Poulovassilis, A.'	5.50	56
125	'current'	'Bailey, J.'	NULL	56

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

Listing any movements for all customers

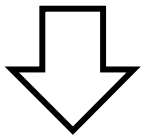
```
SELECT cname,
       mid
FROM   account NATURAL LEFT JOIN
       movement
```



cname	mid
McBrien, P.	1000
McBrien, P.	1001
McBrien, P.	1002
Poulovassilis, A.	1004
Boyd, M.	1005
McBrien, P.	1006
Poulovassilis, A.	1007
McBrien, P.	1008
Poulovassilis, A.	1009
Bailey, J.	NULL

RA equivalent of LEFT JOIN

SELECT $A_1, ..., A_n$
FROM R_1 LEFT JOIN R_2 ON O_1 AND ... AND O_i
WHERE P_1
AND ...
AND P_k



$$\pi_{A_1,...,A_n}\sigma_{P_1\wedge...\wedge P_k}(\sigma_{O_1\wedge...\wedge O_i}(R_1 \times R_2) \cup (R_1 - \sigma_{O_1\wedge...\wedge O_i}(R_1 \ltimes R_2) \times \omega(R_2)))$$

- $\omega(R_2)$ returns a row of NULLs with the same number of columns as R_2

Quiz 1: SQL LEFT JOIN ... ON (1)

```
SELECT account.no,
       movement.amount
FROM   account LEFT JOIN movement
               ON account.no=movement.no AND movement.amount<0
```

What is the result of the above query?

A

no	amount

B

no	amount
100	-223.45
107	-100.00

C

no	amount
100	-223.45
101	NULL
103	NULL
107	-100.00
119	NULL
125	NULL

D

no	amount
100	-223.45
101	0.00
103	0.00
107	-100.00
119	0.00
125	0.00

Quiz 2: SQL LEFT JOIN ... ON (2)

```
SELECT  account.no,
        movement.amount
FROM    account LEFT JOIN movement
                ON account.no=movement.no
WHERE   movement.amount<0
```

What is the result of the above query?

A

no	amount

B

no	amount
100	-223.45
107	-100.00

C

no	amount
100	-223.45
101	NULL
103	NULL
107	-100.00
119	NULL
125	NULL

D

no	amount
100	-223.45
101	0.00
103	0.00
107	-100.00
119	0.00
125	0.00

Worksheet: Left, Right and Outer Joins

worksheet_null database

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

OLTP and OLAP

OLTP

- online transactional processing
- reads and writes to a few rows
- 'standard' data processing

```
BEGIN TRANSACTION T1
        UPDATE branch
        SET cash=cash-10000.00
        WHERE sortcode=56

        UPDATE branch
        SET cash=cash+10000.00
        WHERE sortcode=34
COMMIT TRANSACTION T1
```

OLAP

- online analytical processing
- reads many rows
- management information

```
BEGIN TRANSACTION T4
        SELECT SUM(cash)
        FROM branch
COMMIT TRANSACTION T4
```

SQL OLAP features: GROUP BY

movement

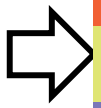
mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	145.50	12/1/1999
1006	100	10.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

```
.
.
.
FROM movement
.
.
.
GROUP BY no
```

SQL OLAP features: GROUP BY

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

. . .
FROM movement
. . .
GROUP BY no



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

Aggregate	Semantics
SUM	Sum the values of all rows in the group
COUNT	Count the number of non-NULL rows in the group
AVG	Average of the non-NULL values in the group
MIN	Minimum value in the group
MAX	Maximum value in the group

. . .

GROUP BY

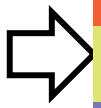
- Only one row output per group
- *ANSI SQL says must apply aggregate function to non grouped columns*

SQL OLAP features: GROUP BY

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

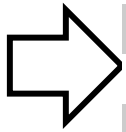
```
.
.
.
FROM movement
.
.
.
GROUP BY no
```



movement

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

```
SELECT  no,
        SUM(amount) AS balance,
        COUNT(amount) AS no_trans
FROM    movement
GROUP BY no
```



no	balance	no_trans
100	2086.78	3
101	5230.00	2
103	145.50	1
107	245.56	2
119	5600.00	1

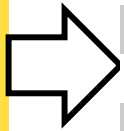
GROUP BY

- Only one row output per group
- *ANSI SQL says must apply aggregate function to non grouped columns*

SQL OLAP features: Aggregate operators

- Normally use GROUP BY on all non aggregated attributes:

```
SELECT no,
       SUM(amount) AS total,
       COUNT(amount) AS trans
FROM   movement
GROUP BY no
```



no	total	trans
119	5600.00	1
107	245.56	2
103	145.50	1
101	5230.00	2
100	2086.78	3

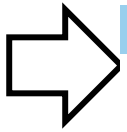
- Don't forget to choose bag or set semantics for COUNT

```
SELECT COUNT(DISTINCT no) AS active_accounts
FROM   movement
```

active_accounts
5

- NULL attributes don't count!

```
SELECT COUNT(rate) AS no_rates
FROM   account
```



no_rates
2

Quiz 3: GROUP BY over NULL values (1)

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
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

```
SELECT  movement.no,
        COUNT(movement.amount) AS no_trans,
        MIN(movement.amount) AS min_value
FROM    movement NATURAL JOIN account
GROUP BY movement.no
```

What is the result of the above query?

A

no	no_trans	min_value
119	2	45.00
101	2	1230.00
107	1	-100.00
100	3	-223.45
103	1	145.50

B

no	no_trans	min_value
101	2	1230.00
100	4	-223.45
119	2	45.00

C

no	no_trans	min_value
101	2	1230.00
100	4	NULL
119	2	45.00

D

no	no_trans	min_value
101	2	1230.00
100	3	-223.45
119	2	45.00

Quiz 4: GROUP BY over NULL values (2)

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
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

```
SELECT  movement.no,
        SUM(movement.amount)  AS  balance
FROM    movement
GROUP  BY  movement.no
```

What is the result of the above query?

A

no	balance
NULL	NULL
NULL	600.00
NULL	-46.00
119	5645.00
101	5230.00
100	2086.78

B

no	balance
NULL	600.00
NULL	-46.00
119	5645.00
101	5230.00
100	2086.78

C

no	balance
NULL	554.00
119	5645.00
101	5230.00
100	2086.78

D

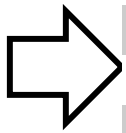
no	balance
119	5645.00
101	5230.00
100	2086.78

Selecting results from aggregates: HAVING

GROUP BY in the RA

- An extension to the RA includes a group by operator
- In SQL, the GROUP BY operator is applied *outside* the $\sigma_P(\ldots \times \ldots)$
- To execute a σ_P *outside* the GROUP BY, you must place the predicates P in a HAVING clause

```
SELECT    no,
          SUM(amount) AS balance,
          COUNT(amount) AS no_trans
FROM      movement
GROUP BY  no
```



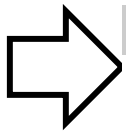
no	balance	no_trans
100	2086.78	3
101	5230.00	2
103	145.50 7	1
107	245.56	2
119	5600.00	1

Selecting results from aggregates: HAVING

GROUP BY in the RA

- An extension to the RA includes a group by operator
- In SQL, the GROUP BY operator is applied *outside* the $\sigma_P(\ldots \times \ldots)$
- To execute a σ_P *outside* the GROUP BY, you must place the predicates P in a HAVING clause

```
SELECT   no,
         SUM(amount) AS balance,
         COUNT(amount) AS no_trans
FROM     movement
GROUP BY no
HAVING   SUM(amount)>2000
```



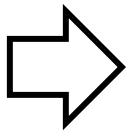
no	balance	no_trans
100	2086.78	3
101	5230.00	2
119	5600.00	1

Selecting results from aggregates: HAVING

GROUP BY in the RA

- An extension to the RA includes a group by operator
- In SQL, the GROUP BY operator is applied *outside* the $\sigma_P(\ldots \times \ldots)$
- To execute a σ_P *outside* the GROUP BY, you must place the predicates P in a HAVING clause

```
SELECT   no,
         SUM(amount) AS balance,
         COUNT(amount) AS no_trans
FROM     movement
GROUP BY no
HAVING   balance>2000
```



column balance does not exist

Ordering of SQL clauses

- HAVING is executed after GROUP BY, but before SELECT
- Can be used to avoid divide by zero errors

```
SELECT   no, SUM(amount)/COUNT(amount) AS average_credit
FROM     movement
WHERE    amount>0
GROUP BY no
HAVING   COUNT(amount)<>0
```

Quiz 5: HAVING

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

```
SELECT   account.no,
         account.cname,
         SUM(movement.amount) AS balance
FROM     account NATURAL JOIN movement
WHERE    movement.amount>200
GROUP BY account.no,
         account.cname
HAVING   COUNT(movement.no)>1
AND      SUM(movement.amount)>1000
```

What is the result of the above query?

A

no	cname	balance
101	McBrien, P.	5230.00

B

no	cname	balance
101	McBrien, P.	5230.00
119	Poulovassilis, A.	5600.00

C

no	cname	balance
100	McBrien, P.	2086.78
101	McBrien, P.	5230.00

D

no	cname	balance
100	McBrien, P.	2086.78
101	McBrien, P.	5230.00
119	Poulovassilis, A.	5600.00

SQL OLAP features: PARTITION

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

.
.
.
OVER (PARTITION BY no)
FROM movement
.
.
.

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

SQL OLAP features: PARTITION

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

```
.
.
.
OVER (PARTITION BY no)
FROM movement
.
.
.
```

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

```
SELECT  mid,
        no,
        amount,
        SUM(amount) OVER (PARTITION BY no) AS balance
FROM    movement
```

mid	no	amount	balance
1000	100	2300.00	2086.78
1002	100	-223.45	2086.78
1006	100	10.23	2086.78
1001	101	4000.00	5230.00
1008	101	1230.00	5230.00
1004	107	-100.00	245.56
1007	107	345.56	245.56
1005	103	145.50	145.50
1009	119	5600.00	5600.00

PARTITION BY

- One row output per input row
- Aggregates apply to partition

Relationally Complete SQL

Relational Completeness

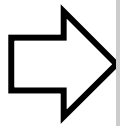
- Relational completeness in SQL means being able to fully support the RA in SQL
- 'pure' RA can be fully supported by SQL
- Aggregates require 'relationally complete' SQL
  - Temporary tables
  - SELECT statements in FROM clause

Relationally Complete SQL

Relational Completeness

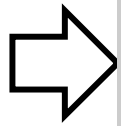
- Relational completeness in SQL means being able to fully support the RA in SQL
- 'pure' RA can be fully supported by SQL
- Aggregates require 'relationally complete' SQL
  - Temporary tables
  - SELECT statements in FROM clause

```
SELECT SUM(amount) AS total
INTO   #total_balance
FROM   movement
```



#total_balance
total
13307.84

```
SELECT    movement.no,
          SUM(movement.amount) AS balance,
          ROUND(100*SUM(movement.amount)/
                #total_balance.total,1) AS pc
FROM      movement,
          #total_balance
GROUP BY  movement.no,#total_balance.total
ORDER BY  movement.no
```



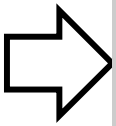
no	balance	pc
100	2086.78	15.7
101	5230.00	39.3
103	145.50	1.1
107	245.56	1.8
119	5600.00	42.1

Relationally Complete SQL

Relational Completeness

- Relational completeness in SQL means being able to fully support the RA in SQL
- 'pure' RA can be fully supported by SQL
- Aggregates require 'relationally complete' SQL
  - Temporary tables
  - SELECT statements in FROM clause

```
SELECT   movement.no,
         SUM(movement.amount) AS balance,
         ROUND(100*SUM(movement.amount)/total_balance.total,1) AS pc
FROM     movement,
         (SELECT SUM(amount) AS total FROM movement) total_balance
GROUP BY movement.no, total_balance.total
ORDER BY movement.no
```

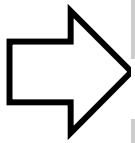


no	balance	pc
100	2086.78	15.7
101	5230.00	39.3
103	145.50	1.1
107	245.56	1.8
119	5600.00	42.1

SQL OLAP features: Ordering Rows

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

```
SELECT    mid,
          tdate,
          amount
FROM      movement
ORDER BY  mid
```



mid	tdate	amount
1000	1999-01-05	2300.00
1001	1999-01-05	4000.00
1002	1999-01-08	-223.45
1004	1999-01-11	-100.00
1005	1999-01-12	145.50
1006	1999-01-15	10.23
1007	1999-01-15	345.56
1008	1999-01-15	1230.00
1009	1999-01-18	5600.00

SQL OLAP features: Ranking Rows

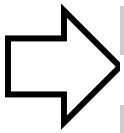
```
SELECT  mid,
        tdate,
        amount,
        RANK() OVER
           (ORDER BY amount DESC) AS rank
FROM    movement
```

mid	tdate	amount	rank
1009	1999-01-18	5600.00	1
1001	1999-01-05	4000.00	2
1000	1999-01-05	2300.00	3
1008	1999-01-15	1230.00	4
1007	1999-01-15	345.56	5
1005	1999-01-12	145.50	6
1006	1999-01-15	10.23	7
1004	1999-01-11	-100.00	8
1002	1999-01-08	-223.45	9

- RANK function provides normal concept of ranking values in order
- DENSE_RANK function will not skip numbers where previous values are identical
- Only in Postgres since verison 9.0

SQL OLAP features: Ranking Rows Without RANK()

```
SELECT   movement.mid,
         movement.tdate,
         movement.amount,
         COUNT(higher.mid) AS rank
FROM     movement JOIN movement higher
         ON movement.amount<higher.amount
         OR movement.mid=higher.mid
GROUP BY movement.mid,
         movement.tdate,
         movement.amount
ORDER BY COUNT(higher.mid)
```



mid	tdate	amount	rank
1009	1999-01-18	5600.00	1
1001	1999-01-05	4000.00	2
1000	1999-01-05	2300.00	3
1008	1999-01-15	1230.00	4
1007	1999-01-15	345.56	5
1005	1999-01-12	145.50	6
1006	1999-01-15	10.23	7
1004	1999-01-11	-100.00	8
1002	1999-01-08	-223.45	9

Quiz 6: Execution of SQL clauses

SELECT
FROM
WHERE
GROUP BY
HAVING
ORDER BY

What order are the SQL clauses executed in?

A

SELECT
FROM
WHERE
GROUP BY
HAVING
ORDER BY

B

FROM
WHERE
SELECT
GROUP BY
HAVING
ORDER BY

C

FROM
WHERE
GROUP BY
HAVING
SELECT
ORDER BY

D

ORDER BY
HAVING
GROUP BY
WHERE
FROM
SELECT

Bank Branch Database

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)

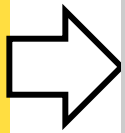
movement(no) $\stackrel{fk}{\Rightarrow}$ account(no)

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

SQL OLAP features: Roll Up and Drill Down

- Often want to look at data at different levels of detail
- **rollup** or **aggregation** combines values together into single values
- **rolldown** or **drill down** breaks single values into multiple values

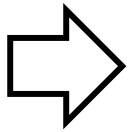
```
SELECT   cname, account.no, mid, amount
FROM     account LEFT JOIN movement
         ON account.no=movement.no
ORDER BY cname, account.no, mid
```



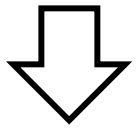
cname	no	mid	amount
Bailey, J.	125	NULL	NULL
Boyd, M.	103	1005	145.50
McBrien, P.	100	1000	2300.00
McBrien, P.	100	1002	-223.45
McBrien, P.	100	1006	10.23
McBrien, P.	101	1001	4000.00
McBrien, P.	101	1008	1230.00
Poulovassilis, A.	107	1004	-100.00
Poulovassilis, A.	107	1007	345.56
Poulovassilis, A.	119	1009	5600.00

OLAP: The concept of Roll Up

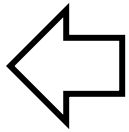
cname	no	mid	amount
Bailey, J.	125	NULL	NULL
Boyd, M.	103	1005	145.50
McBrien, P.	100	1000	2300.00
McBrien, P.	100	1002	-223.45
McBrien, P.	100	1006	10.23
McBrien, P.	101	1001	4000.00
McBrien, P.	101	1008	1230.00
Poulovassilis, A.	107	1004	-100.00
Poulovassilis, A.	107	1007	345.56
Poulovassilis, A.	119	1009	5600.00



cname	no	amount
Bailey, J.	125	NULL
Boyd, M.	103	145.50
McBrien, P.	100	2086.78
McBrien, P.	101	5230.00
Poulovassilis, A.	107	245.56
Poulovassilis, A.	119	5600.00



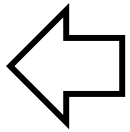
cname	amount
Bailey, J.	NULL
Boyd, M.	145.50
McBrien, P.	7316.78
Poulovassilis, A.	5845.56



amount
13307.84

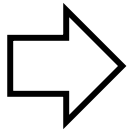
OLAP: The concept of Drill Down

cname	no	mid	amount
Bailey, J.	125	NULL	NULL
Boyd, M.	103	1005	145.50
McBrien, P.	100	1000	2300.00
McBrien, P.	100	1002	-223.45
McBrien, P.	100	1006	10.23
McBrien, P.	101	1001	4000.00
McBrien, P.	101	1008	1230.00
Poulovassilis, A.	107	1004	-100.00
Poulovassilis, A.	107	1007	345.56
Poulovassilis, A.	119	1009	5600.00



cname	no	amount
Bailey, J.	125	NULL
Boyd, M.	103	145.50
McBrien, P.	100	2086.78
McBrien, P.	101	5230.00
Poulovassilis, A.	107	245.56
Poulovassilis, A.	119	5600.00

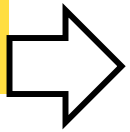
amount
13307.84



cname	amount
Bailey, J.	NULL
Boyd, M.	145.50
McBrien, P.	7316.78
Poulovassilis, A.	5845.56

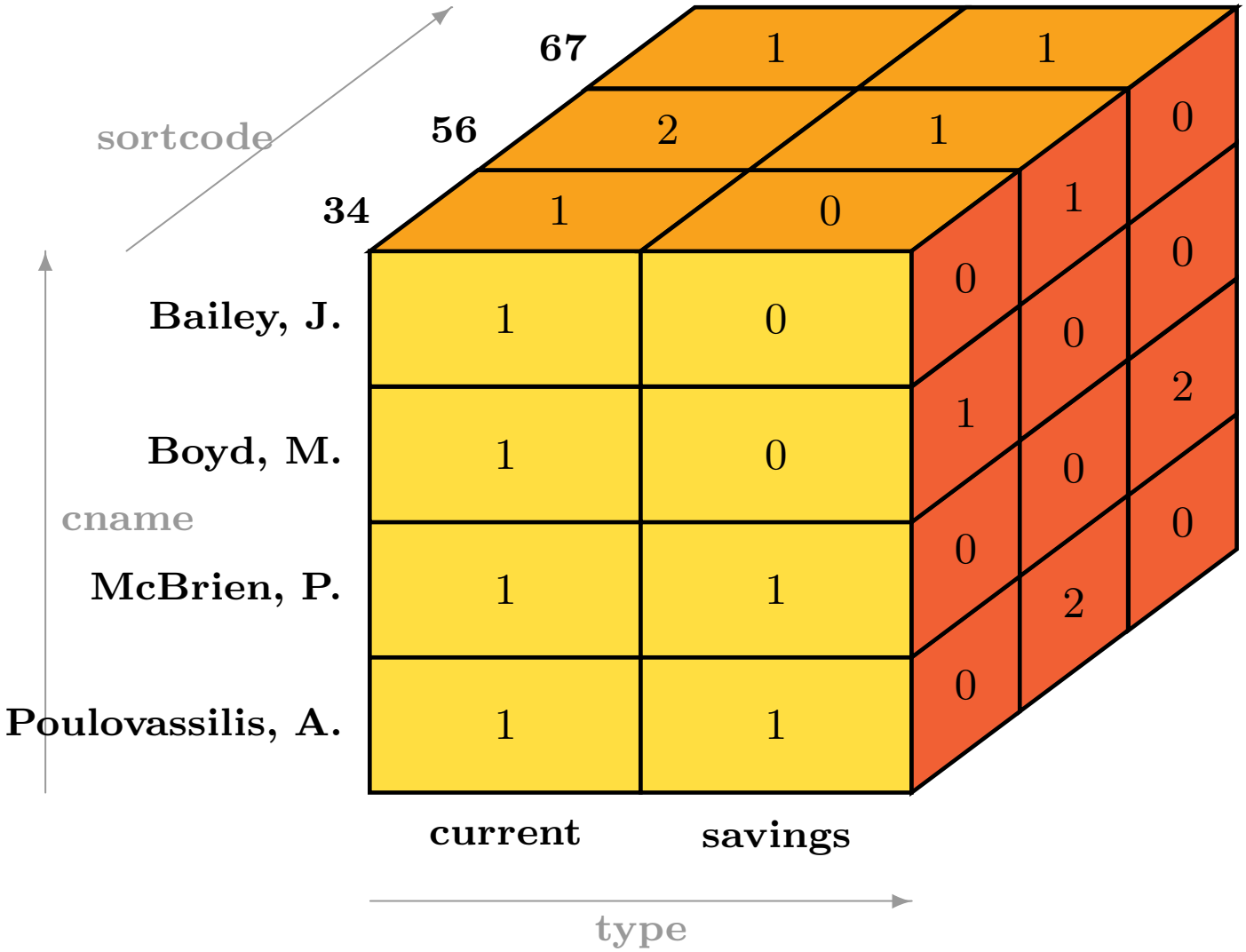
SQL OLAP features: ROLLUP

```
SELECT    cname, account.no,
          mid, SUM(amount) AS amount
FROM      account LEFT JOIN movement
          ON account.no=movement.no
GROUP BY  cname, account.no, mid
          WITH ROLLUP
```



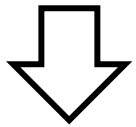
cname	no	mid	amount
Bailey, J.	125	NULL	NULL
Bailey, J.	125	NULL	NULL
Bailey, J.	NULL	NULL	NULL
Boyd, M.	103	1005	145.50
Boyd, M.	103	NULL	145.50
Boyd, M.	NULL	NULL	145.50
McBrien, P.	100	1000	2300.00
McBrien, P.	100	1002	-223.45
McBrien, P.	100	1006	10.23
McBrien, P.	100	NULL	2086.78
McBrien, P.	101	1001	4000.00
McBrien, P.	101	1008	1230.00
McBrien, P.	101	NULL	5230.00
McBrien, P.	NULL	NULL	7316.78
Poulovassilis, A.	107	1004	-100.00
Poulovassilis, A.	107	1007	345.56
Poulovassilis, A.	107	NULL	245.56
Poulovassilis, A.	119	1009	5600.00
Poulovassilis, A.	119	NULL	5600.00
Poulovassilis, A.	NULL	NULL	5845.56
NULL	NULL	NULL	13307.84

OLAP: Multidimensional Cubes



SQL OLAP features: CUBE

```
SELECT   cname, sortcode, type, COUNT(no) AS qty
FROM     account
GROUP BY cname, sortcode, type WITH CUBE
```



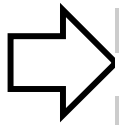
cname	sortcode	type	qty
Bailey, J.	56	current	1
Bailey, J.	56	NULL	1
Bailey, J.	NULL	NULL	1
Boyd, M.	34	current	1
Boyd, M.	34	NULL	1
Boyd, M.	NULL	NULL	1
McBrien, P.	67	current	1
McBrien, P.	67	deposit	1
McBrien, P.	67	NULL	2
McBrien, P.	NULL	NULL	2
Poulovassilis, A.	56	current	1
Poulovassilis, A.	56	deposit	1
Poulovassilis, A.	56	NULL	2
Poulovassilis, A.	NULL	NULL	2
NULL	NULL	NULL	6
NULL	34	current	1

cname	sortcode	type	qty
NULL	34	NULL	1
NULL	56	current	2
NULL	56	deposit	1
NULL	56	NULL	3
NULL	67	current	1
NULL	67	deposit	1
NULL	67	NULL	2
Bailey, J.	NULL	current	1
Boyd, M.	NULL	current	1
McBrien, P.	NULL	current	1
Poulovassilis, A.	NULL	current	1
NULL	NULL	current	4
McBrien, P.	NULL	deposit	1
Poulovassilis, A.	NULL	deposit	1
NULL	NULL	deposit	2

OLAP: Pivot

- for presentation purposes, useful to change layout of table
- information spread over rows is instead spread over columns

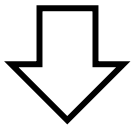
```
SELECT    branch.sortcode,
          branch.bname,
          account.type,
          COUNT(no) AS qty
FROM      account JOIN branch
          ON account.sortcode=
                branch.sortcode
GROUP BY  branch.sortcode,
          branch.bname,
          account.type
ORDER BY  branch.sortcode,
          branch.bname
```



sortcode	bname	type	qty
34	Goodge St	current	1
56	Wimbledon	current	2
56	Wimbledon	deposit	1
67	Strand	current	1
67	Strand	deposit	1

SQL OLAP: Pivot using CASE statements

```
SELECT    branch.sortcode,
          branch.bname,
          COUNT(CASE WHEN type='current' THEN no ELSE NULL END) AS current,
          COUNT(CASE WHEN type='deposit' THEN no ELSE NULL END) AS deposit,
          COUNT(CASE WHEN type NOT IN ('current','deposit') THEN no
          ELSE NULL END) AS other
FROM      account JOIN branch ON account.sortcode=branch.sortcode
GROUP BY  branch.sortcode, branch.bname
ORDER BY  branch.sortcode, branch.bname
```



branch account types pivot

sortcode	bname	current	deposit	other
34	Goodge St	1	0	0
56	Wimbledon	2	1	0
67	Strand	1	1	0

- use CASE statements to filter values from column being pivoted
- one case for each value
- wise to have a default case

Worksheet: OLAP Queries in SQL

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

movement.no $\overset{fk}{\Rightarrow}$ account.no

Worksheet: OLAP Queries in SQL (1)

```
SELECT    movement.no, movement.tdate, movement.amount
FROM      movement
UNION
SELECT    movement.no, NULL AS tdate, SUM(movement.amount)
FROM      movement
GROUP BY movement.no
ORDER BY no,tdate
```

Worksheet: OLAP Queries in SQL (2)

```
SELECT    movement.no, movement.tdate, movement.amount
FROM      movement
UNION
SELECT    account.no, NULL AS tdate, COALESCE(SUM(movement.amount),0)
FROM      account LEFT JOIN movement ON account.no=movement.no
GROUP BY account.no
ORDER BY no,tdate
```

Worksheet: OLAP Queries in SQL (3)

Write an SQL query that lists the cname, no and type of all accounts, together with the account balance (computed as the sum of any movements on the account).

```
SELECT   account.cname,
         account.no,
         account.type,
         COALESCE(SUM(movement.amount),0) AS balance
FROM     account LEFT JOIN movement ON account.no=movement.no
GROUP BY account.cname,
         account.no,
         account.type
```

Worksheet: OLAP Queries in SQL (4)

```
SELECT    account.cname,
          COALESCE(SUM(CASE account.type
                       WHEN 'current' THEN movement.amount
                       ELSE null END),0.0) AS current_balance,
          COALESCE(SUM(CASE account.type
                       WHEN 'deposit' THEN movement.amount
                       ELSE null END),0.0) AS deposit_balance
FROM      account LEFT JOIN movement ON account.no=movement.no
GROUP BY  account.cname
```

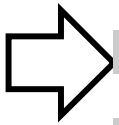
Worksheet: OLAP Queries in SQL (5)

Write an SQL query that lists one row for each account, and for each account, lists the no, cname and type of the account, and in pc_cust_funds the percentage of the customer funds held in the account, and in pc_type_funds the percentage of the total funds in this particular type of account.

```
SELECT DISTINCT account.no,
       account.cname,
       account.type,
       ROUND(COALESCE(100.0*SUM(movement.amount) OVER (PARTITION BY account.no),0.0)/
                SUM(movement.amount) OVER (PARTITION BY account.cname),2)
       AS pc_cust_funds,
       ROUND(COALESCE(100.0*SUM(movement.amount) OVER (PARTITION BY account.no),0.0)/
                SUM(movement.amount) OVER (PARTITION BY account.type),2
       AS pc_type_funds
FROM   account LEFT JOIN movement ON account.no=movement.no
```

SQL OLAP: Un-pivot using UNION statements

```
SELECT  no,
        'cname' AS col,
        cname AS value
FROM    account
UNION
SELECT  no,
        'type',
        type
FROM    account
UNION
SELECT  no,
        'rate',
        CAST(rate AS VARCHAR)
FROM    account
WHERE   rate IS NOT NULL
UNION
SELECT  no,
        'sortcode',
        CAST(sortcode AS VARCHAR)
FROM    account
```



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

Triple Stores

Critism of RDBMS: row format

Some say that

- Sometimes get tables with many (hundreds) of columns, many of which are null
- Adding/removing a column (with ALTER TABLE) is a relatively slow operation, and can break (badly written) queries.

Solutions

- Adopt triple format in RDBMS: performance can be poor due to multiple joins
- Adopt **column store** RDBMS such as SAP **Hana**
- Adopt a Graph/RDF model database such as **StarDog** or **GraphDB**
- ...

Common Table Expressions

Common Table Expressions

The WITH keyword allows a table to be defined that can be used multiple times in a SELECT query.

Finding countries with a common neighbour

borders		
country1	country2	length
A	D	784.00
CZ	D	646.00
D	F	451.00
CH	D	334.00
PL	D	456.00
B	D	167.00
L	D	138.00
NL	D	577.00
DK	D	68.00
	⋮	

```
WITH    uo_border(country1,country2) AS
        (SELECT country1,country2
         FROM   borders
         UNION ALL
         SELECT country2,country1
         FROM   borders
        )
SELECT  uo_border.country1,
        neighbour.country2
FROM    uo_border
        JOIN uo_border AS neighbour
        ON   uo_border.country2=neighbour.country1
WHERE  NOT uo_border.country1=neighbour.country2
ORDER BY uo_border.country1,
        neighbour.country2
```

Recursive SQL

WITH RECURSIVE allows a table to refer to itself

Finding all countries reachable via land borders

```
WITH RECURSIVE
        uo_border(country1,country2) AS
        (SELECT country1,country2
         FROM   borders
         UNION ALL
         SELECT country2,country1
         FROM   borders
        ),
        land_link(country1,country2) AS
        (SELECT *
         FROM   uo_border
         UNION
         SELECT land_link.country1,
                uo_border.country2
         FROM   land_link
                JOIN uo_border
                ON   land_link.country2=uo_border.country1
                AND  NOT land_link.country1=uo_border.country2
        )
SELECT *
FROM   land_link
ORDER BY country1,country2
```

reachable by land

country1	country2
DK	A
DK	AFG
DK	AL
DK	AND
DK	ANG
DK	ARM
DK	AZ
DK	B
⋮	⋮
GB	IRL
⋮	⋮
IRL	GB
⋮	⋮

SQL Views

VIEW

- Implements Datalog rules
- Basic ANSI SQL CREATE VIEW well supported across platforms
- Variations in details

Views defining current account and deposit account

```
CREATE VIEW current_account AS
SELECT no,
       cname,
       sortcode
FROM   account
WHERE  type='current'

CREATE VIEW deposit_account AS
SELECT no,
       cname,
       rate,
       sortcode
FROM   account
WHERE  type='deposit'
```

Quiz 7: Updates to SQL Views

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

```
CREATE VIEW current_account AS
SELECT no,
       cname,
       sortcode
FROM   account
WHERE  type='current'
```

Which SQL view update does not work?

A

```
UPDATE current_account
SET    sortcode=56
WHERE  no=125
```

B

```
UPDATE current_account
SET    sortcode=56
```

C

```
DELETE FROM current_account
WHERE  no=125
```

D

```
INSERT INTO current_account
VALUES (129,'Jones, F.',34)
```

SQL View Updates

SQL restricts View updates to view definitions

- on just one table
- containing no aggregates
- no computed columns
- for INSERT: all non-NULLable columns without defaults being included in view

Ambiguous view updates

```
CREATE VIEW active_account AS
SELECT no,
       cname,
       sortcode
FROM   account JOIN movement ON account.no=movement.no

DELETE FROM active_account
WHERE  no=100
```

The DELETE could be fulfilled by either (a) deleting account 100 or (b) deleting all movements for account 100

SQL Materialised Views

Materialised Views

- cache the result of the view query
- in Oracle, add MATERIALIZED to view creation, use REFRESH to repopulate view
- not standardised or supported accross all platforms

Materialised Views (Oracle Syntax)

```
CREATE MATERIALIZED VIEW current_account AS
SELECT no,
       cname,
       sortcode
FROM   account
WHERE  type='current'

CREATE MATERIALIZED VIEW deposit_account AS
SELECT no,
       cname,
       rate,
       sortcode
FROM   account
WHERE  type='deposit'
```

Active Databases: Constraints

General purpose constraints

- PRIMARY KEY and FOREIGN KEY are examples of constraint rules
- CHECK allows any SQL code to be run after a table is updated

IF account(No, _, _, Rate, _) THEN Rate $\geq$ 0.00

```
ALTER TABLE account
ADD CONSTRAINT check_account_rate
CHECK (rate >=0.00)
```

Cascading UPDATE and DELETE operations

- Can cascade updates on one column to other columns that reference that column

```
CONSTRAINT account_fk FOREIGN KEY (sortcode)
REFERENCES branch ON UPDATE CASCADE
```

- Can cascade deletes on one column to other columns that reference that column

```
CONSTRAINT movement_fk FOREIGN KEY (no)
REFERENCES account ON DELETE CASCADE
```

Active Databases: Triggers

Trigger

A **trigger** causes a change on some table to cause a block of SQL to be executed. Implementations vary, but the SQL Standard says:

- Cause execution of procedure when an INSERT, DELETE, or UPDATE occurs
- Can be FOR EACH ROW or FOR EACH STATEMENT
- Can execute BEFORE or AFTER the change is made

IF account(No, CN, 'current', _, SC) THEN current_account(No, CN, SC) Implemented Using SQL Server Triggers

```
CREATE TRIGGER insert_current_account
ON account AFTER INSERT AS
INSERT INTO current_account
SELECT INSERTED.no,
       INSERTED.cname,
       INSERTED.sortcode
FROM   INSERTED
WHERE  INSERTED.type='current'
```

Triggers: Implementing Constraints

```
CREATE FUNCTION delete_only_cleared_accounts() RETURNS TRIGGER
AS
DECLARE account_balance DECIMAL(10,2);
BEGIN
      SELECT INTO account_balance SUM(amount)
      FROM    movement
      WHERE   movement.no=OLD.no;

      IF (account_balance<>0 AND account_balance IS NOT NULL) THEN
        RAISE EXCEPTION 'Unable to delete account % since it has balance of %',
                        OLD.no,
                        account_balance;
      END IF;

      RETURN OLD;
END
LANGUAGE plpgsql;

CREATE TRIGGER check_no_balance
BEFORE DELETE ON account FOR EACH ROW
EXECUTE PROCEDURE delete_only_cleared_accounts();
```

Triggers: Implementing Active Databases

```
CREATE FUNCTION delete_redundant_account() RETURNS TRIGGER
AS BEGIN
      DELETE FROM account
      WHERE  account.cname=OLD.cname
      AND NOT EXISTS (SELECT cname
                      FROM   account
                      WHERE  account.cname=OLD.cname
                      AND    type='current');

      RETURN NULL;
   END
LANGUAGE plpgsql;

CREATE TRIGGER check_no_other_accounts
AFTER DELETE ON account FOR EACH ROW
EXECUTE PROCEDURE delete_redundant_account();
```

Worksheet: Active Databases (1)

```
CREATE TABLE site
(       sitecode CHAR(4) NOT NULL,
        area INTEGER NOT NULL,
        postcode VARCHAR(20) NOT NULL,
        CONSTRAINT site_pk PRIMARY KEY (sitecode)
)

CREATE TABLE branch
(       sortcode CHAR(9) NOT NULL,
        name VARCHAR(20) NOT NULL,
        cash DECIMAL(10,2) NOT NULL,
        CONSTRAINT branch_pk PRIMARY KEY (sortcode)
)
```

Worksheet: Bank Branch Database

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)

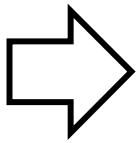
Worksheet: Active Databases (1)

```
CREATE TABLE site
(       sitecode CHAR(4) NOT NULL,
        area INTEGER NOT NULL,
        postcode VARCHAR(20) NOT NULL,
        CONSTRAINT site_pk PRIMARY KEY (sitecode)
)

CREATE TABLE branch
(       sortcode CHAR(9) NOT NULL,
        name VARCHAR(20) NOT NULL,
        cash DECIMAL(10,2) NOT NULL,
        sitecode CHAR(4) NOT NULL,
        CONSTRAINT branch_pk PRIMARY KEY (sortcode),
        CONSTRAINT branch_fk FOREIGN KEY (sitecode)
            REFERENCES site ON DELETE CASCADE
)
```

Worksheet: Active Databases (2)

```
SELECT no,
       SUM(amount) AS balance
FROM   movement
GROUP BY no
```



no	balance
100	2086.78
101	5230.00
103	145.50
107	245.56
119	5600.00

Worksheet: Active Databases (3)

```
CREATE FUNCTION delete_redundant_account() RETURNS TRIGGER
AS 'BEGIN
      DELETE FROM account
      WHERE account.cname=OLD.cname
      AND NOT EXISTS (SELECT cname
          FROM account
          WHERE account.cname=OLD.cname
          AND NOT account.no=OLD.no
          AND type=\'current\');

      RETURN OLD;
END'
LANGUAGE plpgsql;

CREATE TRIGGER check_no_other_accounts
BEFORE DELETE ON account FOR EACH ROW
EXECUTE PROCEDURE delete_redundant_account();
```

Summary of Operational Semantics in RDBMS

At a logical level, we want to maintain rules of the form

IF x THEN y

Operation Semantics: Integrity Constraints

Keys, foreign keys and CHECK constrains all work to ensure the if a change to the database is attempted to break the logical rule, then a change is rejected.

Operation Semantics: Views

A VIEW means that the values of y can be derived by running a query that tests for x

Operation Semantics: Triggers

A TRIGGER can be written to ensure that if a change occurs that makes x true, then another change occurs that makes y true.