SQL language: basics

Nested queries

Nested queries

- Introduction
- The IN operator
- The NOT IN operator
- The tuple constructor
- The EXISTS operator
- The NOT EXISTS operator
- Correlation among queries
- The division operation
- Table functions

Nested queries

Introduction

Introduction

- A nested query is a SELECT statement contained within another query
  - query nesting allows decomposing a complex problem into simpler subproblems
- SELECT statements may be introduced
  - within a predicate in the WHERE clause
  - within a predicate in the HAVING clause
  - in the FROM clause

Supplier and part DB (1/2)

- P (PId, PName, Color, Size, Store)
- S (SId, SName, #Employees, City)
- SP (SId, PId, Qty)

Supplier and part DB (1/2)

P

PId	PName	Color	Size	Store
P1	Jumper	Red	40	London
P2	Jeans	Green	48	Paris
P3	Blouse	Blue	48	Rome
P4	Blouse	Red	44	London
P5	Skirt	Blue	40	Paris
P6	Shorts	Red	42	London

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

Nested queries (no.1)

- Find the codes of the suppliers that are based in the same city as S1

- By using a formulation with nested queries, the problem may be decomposed into two subproblems
  - city of supplier S1
  - codes of the suppliers based in the same city

Nested queries (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT SId
FROM S
WHERE City = (SELECT City
              FROM S
              WHERE SId='S1');
```

- The '=' operator may be used only if it is known in advance that the inner SELECT statement always returns a single value

Equivalent formulation (no.1)

- Find the codes of the suppliers that are based in the same city as S1
- An equivalent formulation may be defined using a join operation

Equivalent formulation

- The equivalent formulation with join is characterized by
  - a FROM clause including the tables referenced by the FROM clauses of each SELECT statement
  - appropriate join conditions in the WHERE clause
  - possible selection predicates added in the WHERE clause

FROM clause (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT SId
FROM S                          SX
WHERE City = (SELECT City
              FROM S            SY
              WHERE SId='S1');
```

FROM clause (no.1)

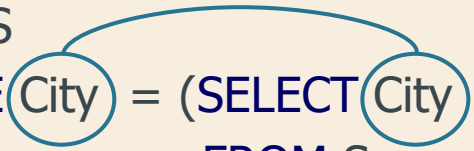
- Find the codes of the suppliers that are based in the same city as S1

```
SELECT ...
FROM S AS SX, S AS SY
...
```

Join condition (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT SId
FROM S
WHERE City = (SELECT City
              FROM S
              WHERE SId='S1');
```



Join condition (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT …
FROM S AS SX, S AS SY
WHERE SX.City=SY.City
…
```

Selection predicate (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT SId
FROM S
WHERE City = (SELECT City
                FROM S
                WHERE SId='S1');
```

SELECT clause (no.1)

- Find the codes of the suppliers that are based in the same city as S1

```
SELECT SY.SId
FROM S AS SX, S AS SY
WHERE SX.City=SY.City AND
      SX.SId='S1';
```

Equivalent formulation (no.2)

- Find the codes of the suppliers whose number of employees is smaller than the maximum number of employees

```
SELECT SId
FROM S
WHERE #Employees < (SELECT MAX(#Employees)
                    FROM S);
```

- Is it possible to define an equivalent formulation with join?

Equivalent formulation (no.2)

- Find the codes of the suppliers whose number of employees is smaller than the maximum number of employees

```
SELECT SId
FROM S
WHERE #Employees < (SELECT MAX(#Employees)
                    FROM S);
```

- An equivalent formulation with join is not possible

Nested queries

The IN operator

The IN operator (no.1)

- Find the names of the suppliers that provide product P2
- Decomposition of the problem into two subproblems
  - codes of the suppliers of product P2
  - names of the suppliers with such codes

The IN operator (no.1)

- Find the names of the suppliers that provide product P2

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

SId
S1
S2
S3

```
(SELECT SId
 FROM SP
 WHERE PId='P2')
```

Codes of the suppliers of P2

The IN operator (no.1)

- Find the names of the suppliers that provide product P2

```
SELECT SName
FROM S
WHERE SId     (SELECT SId
                FROM SP
                WHERE PId='P2')
```

The IN operator (no.1)

- Find the names of the suppliers that provide product P2

```
SELECT SName
FROM S
WHERE SId ◯ (SELECT SId
             FROM SP
             WHERE PId='P2')
```

?

The IN operator (no.1)

- Find the names of the suppliers that provide product P2

Set membership

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId='P2');
```

The IN operator

- It expresses the concept of membership to a set of values
  - *AttributeName* IN *(NestedQuery)*
- It allows writing a query by
  - decomposing the problem into subproblems
  - following a "bottom-up" procedure

Equivalent formulation

- The equivalent formulation with join is characterized by
  - a FROM clause including the tables referenced by the FROM clauses of each SELECT statement
  - appropriate join conditions in the WHERE clause
  - possible selection predicates added in the WHERE clause

The IN operator (no.1)

- Find the names of the suppliers that provide product P2

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId='P2');
```

Equivalent formulation (no.1)

- Find the names of the suppliers that provide product P2

```
SELECT SName
FROM S, SP
WHERE S.SId=SP.SId
        AND PId='P2';
```

The IN operator (no.2)

- Find the names of the suppliers that supply at least one red product

- Decomposition of the problem into subproblems
  - codes of the red products
  - codes of the suppliers of such products
  - names of the suppliers with such codes

The IN operator (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
                    FROM SP
                    WHERE PId IN (SELECT PId
                                        FROM P
                                        WHERE Color='Red'));
```

Equivalent formulation (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
                FROM SP
                WHERE PId IN (SELECT PId
                              FROM P
                              WHERE Color='Red'));
```

FROM clause (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
                FROM SP
                WHERE PId IN (SELECT PId
                              FROM P
                              WHERE Color='Red'));
```

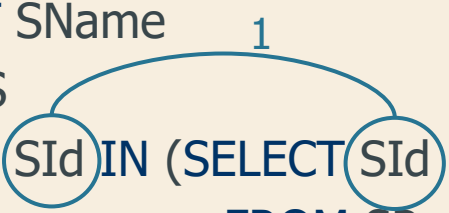
FROM clause (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT ...
FROM S, SP, P
...
```

Join conditions (no.2)

- Find the names of the suppliers that supply at least one red product




```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId IN (SELECT PId
                            FROM P
                            WHERE Color='Red'));
```

Join conditions (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT ...
FROM S, SP, P
WHERE S.SId=SP.SId
```

1

Join conditions (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId IN (SELECT PId
                            FROM P
                            WHERE Color='Red'));
```

2

Join conditions (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT ...
FROM S, SP, P
WHERE S.SId=SP.SId AND
      SP.CodP=S.CodP
      ...
```

2

Selection predicate (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
                    FROM SP
                    WHERE PId IN (SELECT PId
                                        FROM P
                                        WHERE Color='Red'));
```

SELECT clause (no.2)

- Find the names of the suppliers that supply at least one red product

```
SELECT DISTINCT SName
FROM S, SP, P
WHERE S.SId=SP.SId AND
      SP.PId=P.PId AND
      Color='Red';
```

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

P

PId	PName	Color	Size	Store
P1	Jumper	Red	40	London
P2	Jeans	Green	48	Paris
P3	Blouse	Blue	48	Rome
P4	Blouse	Red	44	London
P5	Skirt	Blue	40	Paris
P6	Shorts	Red	42	London

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

- The formulation with join is awkward
  - it is easier to decompose the problem into subproblems through nested queries

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

Codes of the red products

```
SELECT PId
FROM P
WHERE Color='Red'
```

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

```
SELECT SId
FROM SP
WHERE PId IN
        (SELECT PId
         FROM P
         WHERE Color='Red')
```

Codes of the suppliers of red products

A complex example (no.3)

- Find the names of the suppliers that supply at least one product supplied by suppliers of red products

Codes of the products supplied by suppliers of red products

```
SELECT PId
 FROM SP
 WHERE SId IN
            (SELECT SId
             FROM SP
             WHERE PId IN
                        (SELECT PId
                         FROM P
                         WHERE Color='Red'))
```

A complex example (no.3)

```
SELECT SId
FROM SP
WHERE PId IN
          (SELECT PId
           FROM SP
           WHERE SId IN
                     (SELECT SId
                      FROM SP
                      WHERE PId IN
                                (SELECT PId
                                 FROM P
                                 WHERE Color='Red')))
```

Codes of the suppliers of the products supplied by suppliers of red products

Complete query (no.3)

```
SELECT SName
FROM S
WHERE SId IN
            (SELECT SId
             FROM SP
             WHERE PId IN
                        (SELECT PId
                         FROM SP
                         WHERE SId IN
                                    (SELECT SId
                                     FROM SP
                                     WHERE PId IN
                                                (SELECT PId
                                                 FROM P
                                                 WHERE Color='Red'))));
```

Formulation with join (no.3)

Formulation with join (no.3)

```
SELECT SName
FROM S
WHERE SId IN
            (SELECT SId
             FROM SP
             WHERE PId IN
                        (SELECT PId
                         FROM SP
                         WHERE SId IN
                                    (SELECT SId
                                     FROM SP
                                     WHERE PId IN
                                                (SELECT PId
                                                 FROM P
                                                 WHERE Color='Red'))));
```

FROM clause (no.3)

```
SELECT SName
FROM S
WHERE SId IN
        (SELECT SId
         FROM SP
         WHERE PId IN
                 (SELECT PId
                  FROM SP
                  WHERE SId IN
                          (SELECT SId
                           FROM SP
                           WHERE PId IN
                                   (SELECT PId
                                    FROM P
                                    WHERE Color='Red'))));
```

FROM clause (no.3)

```
SELECT SName
FROM S
WHERE SId IN
        (SELECT SId
         FROM SP
         WHERE PId IN
                 (SELECT PId
                  FROM SP
                  WHERE SId IN
                          (SELECT SId
                           FROM SP
                           WHERE PId IN
                                   (SELECT PId
                                    FROM P
                                    WHERE Color='Red'))));
```

SPA

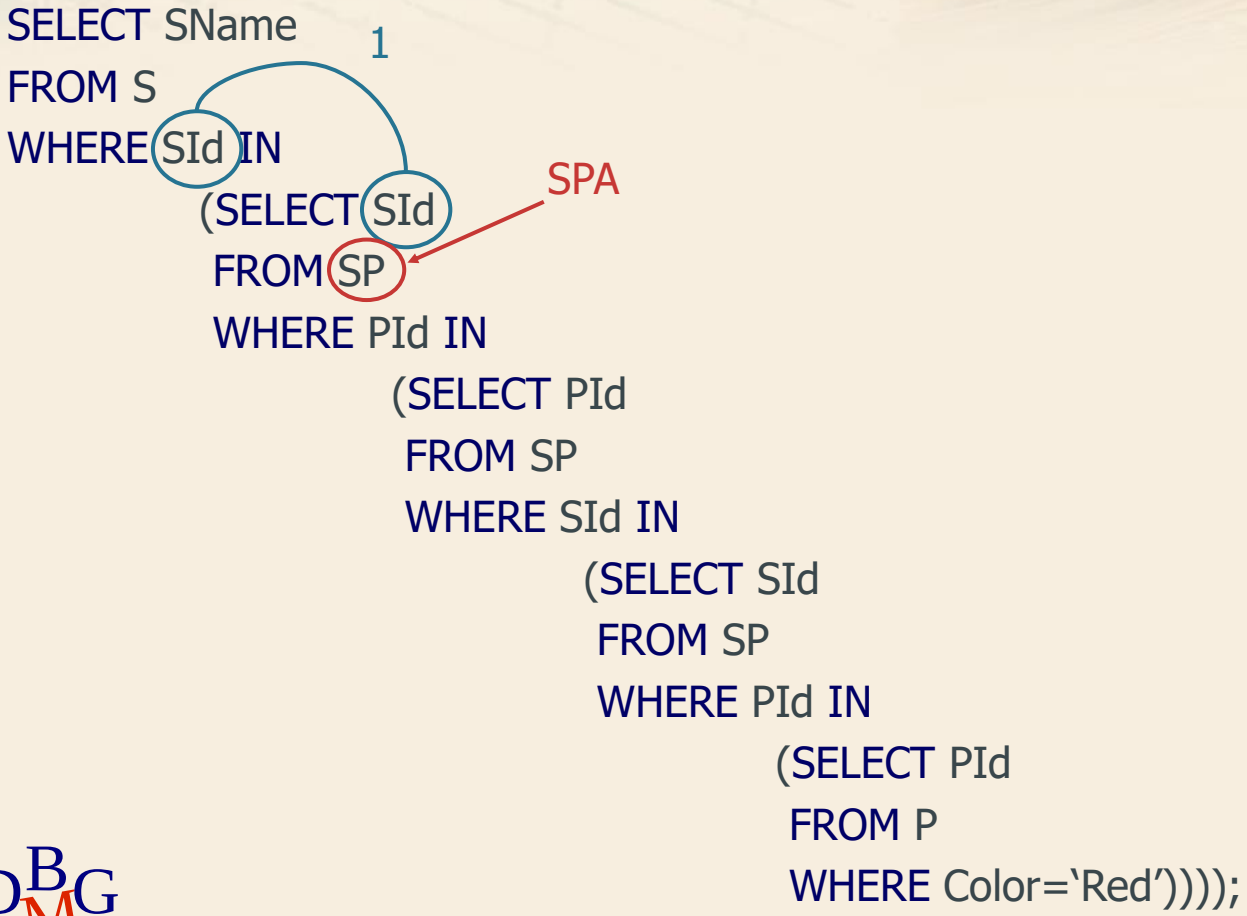
SPB

SPC

FROM clause (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
...
```

Join conditions (no.3)

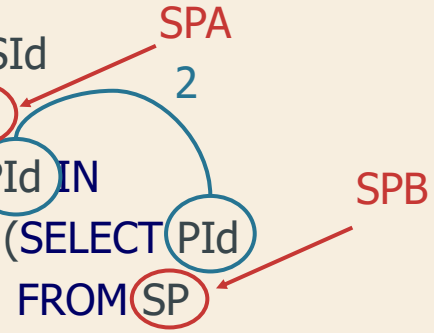


Join conditions (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId          (1)
          ...
```

Join conditions (no.3)

```
SELECT SName
FROM S
WHERE SId IN
        (SELECT SId
         FROM SP
         WHERE PId IN
                 (SELECT PId
                  FROM SP
                  WHERE SId IN
                          (SELECT SId
                           FROM SP
                           WHERE PId IN
                                   (SELECT PId
                                    FROM P
                                    WHERE Color='Red'))));
```



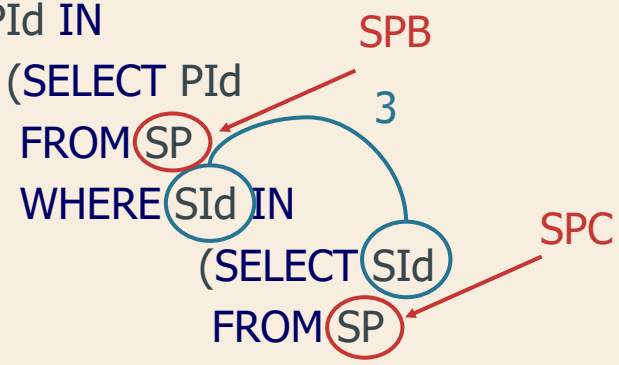
Join conditions (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId AND
        SPA.PId=SPB.PId
        ...
```

2

Join conditions (no.3)

```
SELECT SName
FROM S
WHERE SId IN
          (SELECT SId
           FROM SP
           WHERE PId IN
                    (SELECT PId
                     FROM SP
                     WHERE SId IN
                              (SELECT SId
                               FROM SP
                               WHERE PId IN
                                        (SELECT PId
                                         FROM P
                                         WHERE Color='Red'))));
```



Join conditions (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId AND
        SPA.PId=SPB.PId AND
        SPB.SId=SPC.SId
        ...
```

Join conditions (no.3)

```
SELECT SName
FROM S
WHERE SId IN
            (SELECT SId
             FROM SP
             WHERE PId IN
                        (SELECT PId
                         FROM SP
                         WHERE SId IN
                                    (SELECT SId
                                     FROM SP
                                     WHERE PId IN
                                                (SELECT PId
                                                 FROM P
                                                 WHERE Color='Red'))));
```

Join conditions (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId AND
        SPA.PId=SPB.PId AND
        SPB.SId=SPC.SId AND
        SPC.PId=P.PId
        ...
```

4

Selection predicate (no.3)

```
SELECT SName
FROM S
WHERE SId IN
            (SELECT SId
             FROM SP
             WHERE PId IN
                        (SELECT PId
                         FROM SP
                         WHERE SId IN
                                    (SELECT SId
                                     FROM SP
                                     WHERE PId IN
                                                (SELECT PId
                                                 FROM P
                                                 WHERE Color='Red'))));
```

Selection predicate (no.3)

```
SELECT ...
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId AND
        SPA.PId=SPB.PId AND
        SPB.SId=SPC.SId AND
        SPC.PId=P.PId AND
        Color='Red'
```

SELECT statement (no.3)

```
SELECT DISTINCT SName
FROM S, SP AS SPA, SP AS SPB, SP AS SPC, P
WHERE S.SId=SPA.SId AND
        SPA.PId=SPB.PId AND
        SPB.SId=SPC.SId AND
        SPC.PId=P.PId AND
        Color='Red';
```

Nested queries

The NOT IN operator

Concept of exclusion (no.1)

- Find the names of the suppliers that *do not* supply product P2
  - is it possible to express the query with a join operation?

```
SELECT SName
FROM S, SP
WHERE S.SId=SP.SId
      AND PId<>'P2';
```

Wrong solution (no.1)

- Find the names of the suppliers that *do not* supply product P2
  - the query may not be expressed by means of a join

```
SELECT SName
FROM S, SP
WHERE S.SId=SP.SId
      AND PId<>'P2';
```

Wrong solution (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	*P1*	*300*
S1	P2	200
S1	*P3*	*400*
S1	*P4*	*200*
S1	*P5*	*100*
S1	*P6*	*100*
S2	*P1*	*300*
S2	P2	400
S3	P2	200
S4	*P3*	*200*
S4	*P4*	*300*
S4	*P5*	*400*

R

SName
Smith
Jones
Clark

Wrong solution (no.1)

```
SELECT SName
FROM S, SP
WHERE S.SId=SP.SId
      AND PId<>'P2';
```

- Which query does it answer?

Wrong solution (no.1)

```
SELECT SName
FROM S, SP
WHERE S.SId=SP.SId
      AND PId<>'P2';
```

Find the names of the suppliers that supply at least one product other than P2

Concept of exclusion (no.1)

- Find the names of the suppliers that *do not* supply product P2

- We need to exclude from the result
  - the suppliers that supply product P2

Concept of exclusion (no.1)

- Find the names of the suppliers that *do not* supply product P2

```
SELECT SId
FROM SP
WHERE PId='P2'
```

Codes of the suppliers that supply P2

Concept of exclusion (no.1)

- Find the names of the suppliers that *do not* supply product P2

```
SELECT SName
FROM S
WHERE SId ○ (SELECT SId
            FROM SP
            WHERE PId='P2');
```

?

Codes of the suppliers that supply P2

The NOT IN operator (no.1)

- Find the names of the suppliers that *do not* supply product P2

```
SELECT SName
FROM S
WHERE SId NOT IN (SELECT SId
                  FROM SP
                  WHERE PId='P2');
```

does not belong to

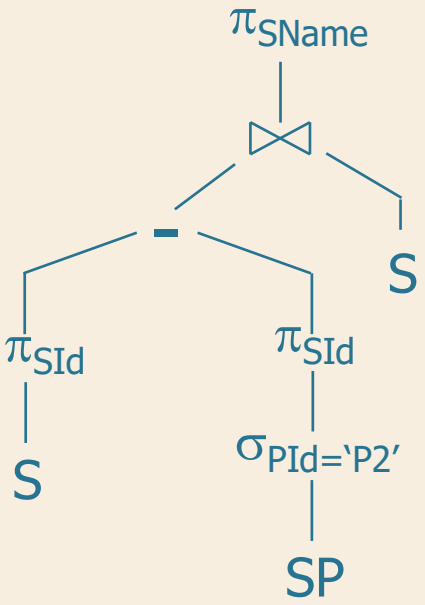
Codes of the suppliers that supply P2

The NOT IN operator

- It expresses the concept of exclusion from a set of values
  - *AttributeName* NOT IN *(NestedQuery)*
- It requires the identification of an appropriate *set to be excluded*
  - defined by the nested query

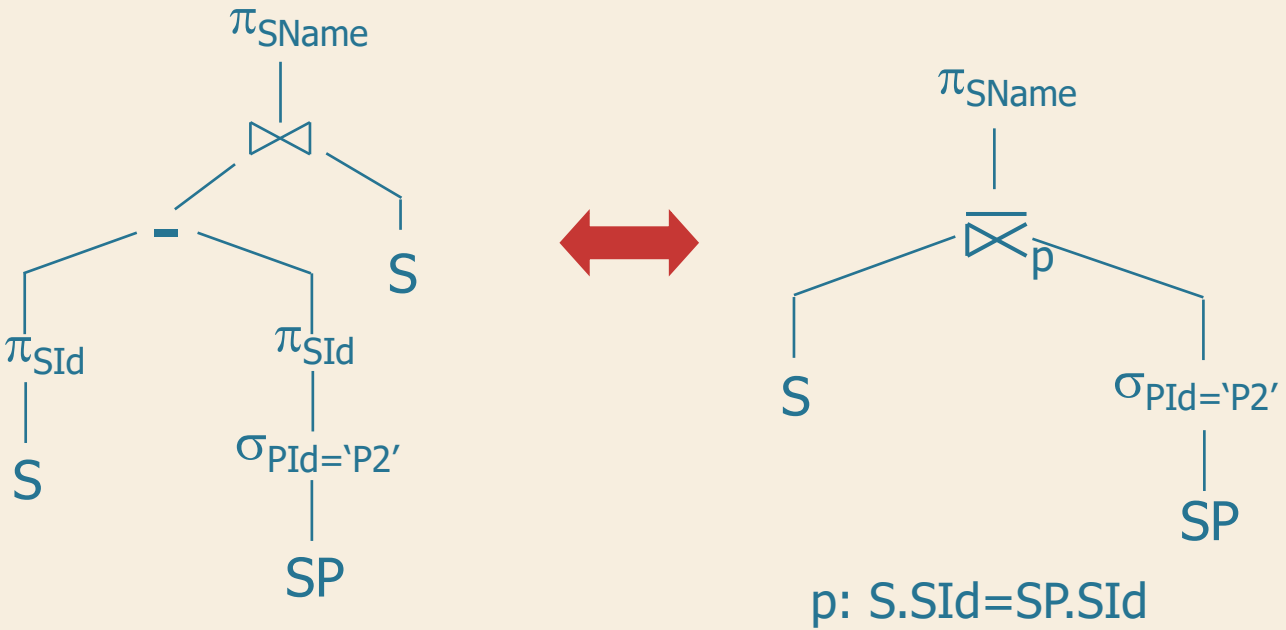
NOT IN and relational algebra (no.1)

- Find the names of the suppliers that *do not* supply product P2



NOT IN and relational algebra (no.1)

- Find the names of the suppliers that *do not* supply product P2



The NOT IN operator (no.2)

- Find the names of the suppliers that *only* supply product P2

Find the names of the suppliers of P2 that have never supplied products other than P2

- Set to be excluded
  - suppliers of products other than P2

The NOT IN operator (no.2)

- Find the names of the suppliers that only supply product P2

```
SELECT SId
FROM SP
WHERE PId<>'P2'
```

Codes of the suppliers that supply at least one product other than P2

The NOT IN operator (no.2)

- Find the names of the suppliers that only supply product P2

```
SELECT SName
FROM S
WHERE SId NOT IN (SELECT SId
                  FROM SP
                  WHERE PId<>'P2')
...
```

The NOT IN operator (no.2)

- Find the names of the suppliers that only supply product P2

```
SELECT SName
FROM S, SP
WHERE S.SId NOT IN (SELECT SId
                    FROM SP
                    WHERE PId<>'P2')
      AND S.SId=SP.SId;
```

Alternative solution (no.2)

- Find the names of the suppliers that only supply product P2

```
SELECT SName
FROM S
WHERE S.SId NOT IN (SELECT SId
                    FROM SP
                    WHERE PId<>'P2')
      AND S.SId IN (SELECT SId
                    FROM SP);
```

The NOT IN operator (no.3)

- Find the names of the suppliers that *do not* supply any red products

- P (PId, PName, Color, Size, Store)
- S (SId, SName, #Employees, City)
- SP (SId, PId, Qty)

The NOT IN operator (no.3)

- Find the names of the suppliers that *do not* supply any red products

- Set to be excluded?
  - suppliers of red products, identified by their codes

The NOT IN operator (no.3)

- Find the names of the suppliers that *do not* supply any red products

Codes of the suppliers of red products

```
(SELECT SId
  FROM SP
  WHERE PId IN  (SELECT PId
                 FROM P
                 WHERE Color='Red')
```

The NOT IN operator (no.3)

- Find the names of the suppliers that *do not* supply any red products

```
SELECT SName
FROM S
WHERE SId NOT IN (SELECT SId
                  FROM SP
                  WHERE PId IN  (SELECT PId
                                 FROM P
                                 WHERE Color='Red'));
```

Alternative (correct?) (no.3)

- Find the names of the suppliers that *do not* supply any red products

Codes of the suppliers that supply at least one non-red product

```
SELECT SId
FROM SP
WHERE PId NOT IN (SELECT PId
                  FROM P
                  WHERE Color='Red')
```

Alternative (correct?) (no.3)

- Find the names of the suppliers that *do not* supply any red products

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId NOT IN (SELECT PId
                                FROM P
                                WHERE Color='Red'));
```

Wrong alternative (no.3)

- Find the names of the suppliers that *do not* supply any red products

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId NOT IN (SELECT PId
                                FROM P
                                WHERE Color='Red'));
```

Wrong alternative (no.3)

- Find the names of the suppliers that *do not* supply any red products

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId NOT IN (SELECT PId
                                FROM P
                                WHERE Color='Red'));
```

Codes of the suppliers of non-red products

Wrong alternative (no.3)

- Find the names of the suppliers that *do not* supply any red products

P

PId	PName	Color	Size	Store
P1	Jumper	Red	40	London
P2	Jeans	Green	48	Paris
P3	Blouse	Blue	48	Rome
P4	Blouse	Red	44	London
P5	Skirt	Blue	40	Paris
P6	Shorts	Red	42	London

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

Wrong alternative (no.3)

- Find the names of the suppliers that *do not* supply any red products

P

PId	PName	Color	Size	Store
P1	Jumper	Red	40	London
P2	Jeans	Green	48	Paris
P3	Blouse	Blue	48	Rome
P4	Blouse	Red	44	London
P5	Skirt	Blue	40	Paris
P6	Shorts	Red	42	London

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

Wrong alternative (no.3)

- Find the names of the suppliers that *do not* supply any red products

```
SELECT SName
FROM S
WHERE SId IN (SELECT SId
              FROM SP
              WHERE PId NOT IN (SELECT PId
                                FROM P
                                WHERE Color='Red'));
```

- The set of elements to be excluded is incorrect

Nested queries

The tuple constructor

The tuple constructor

- It allows defining a temporary structure for a tuple
  - the attributes belonging to the tuple must be listed within ()

$$(AttributeName_1, AttributeName_2, ...)$$

- It enhances the expressive power of the IN and NOT IN operators

Example (no.1)

TRIP (TId, StartingPlace, Destination,
DepartureTime, ArrivalTime)

- Find the pairs of starting places and destinations for which none of the trips lasts more than 2 hours

Example (no.1)

TRIP (TId, StartingPlace, Destination,
DepartureTime, ArrivalTime)

- Find the pairs of starting places and destinations for which none of the trips lasts more than 2 hours

```
SELECT StartingPlace, Destination
FROM TRIP
WHERE (StartingPlace, Destination) NOT IN
      (SELECT StartingPlace, Destination
       FROM  TRIP
       WHERE ArrivalTime-DepartureTime>2);
```

Tuple constructor

Nested queries

The EXISTS operator

The EXISTS operator (no.1)

- Find the names of the suppliers of product P2

Find the names of the suppliers for which there exists a product supply for P2

Correlation condition (no.1)

- Find the names of the suppliers of product P2

```
SELECT SName
FROM S
WHERE EXISTS (SELECT *
                FROM SP
                WHERE PId='P2'
                      AND SP.SId=S.SId );
```

Correlation condition

How EXISTS works (no.1)

- Find the names of the suppliers of product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

```
SELECT *
FROM SP
WHERE PId='P2'
      AND SP.SId='S1'
```

Value of SId in the current line of table S

How EXISTS works (no.1)

- Find the names of the suppliers of product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

- The predicate including EXISTS is true for S1 since there exists a supply for P2 by S1
  - S1 belongs to the result of the query

How EXISTS works (no.1)

- Find the names of the suppliers of product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

- The predicate including EXISTS is false for S4 since there exists no supply for P2 by S4
  - S4 is not included in the result of the query

Result of the query (no.1)

- Find the names of the suppliers of product P2

R

SName
Smith
Jones
Blake

Predicates with EXISTS

- The predicate including EXISTS is
  - true if the inner query returns at least one tuple
  - false if the inner query returns the empty set

Predicates with EXISTS

- The predicate including EXISTS is
  - true if the inner query returns at least one tuple
  - false if the inner query returns the empty set
- In the query inside EXISTS, the SELECT clause is mandatory but irrelevant, since its attributes are never displayed
- The correlation condition binds the execution of the inner query to the values of attributes of the current tuple in the outer query

Scope of attributes

- A nested query may reference attributes defined within outer queries
- A query may not reference attributes defined
  - within a nested query at an inner level
  - within a different query at the same level

Nested queries

The NOT EXISTS operator

The NOT EXISTS operator (no.1)

- Find the names of the suppliers that *do not* supply product P2

Find the names of the suppliers for which there does not exist a product supply for P2

The NOT EXISTS operator (no.1)

- Find the names of the suppliers that *do not* supply product P2

```
SELECT SName
FROM S
WHERE NOT EXISTS (SELECT *
                  FROM SP
                  WHERE PId='P2'
                        AND SP.SId=S.SId );
```

Correlation condition

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

```
SELECT *
FROM SP
WHERE PId='P2' AND
      SP.SId='S1'
```

value of SId in the current line of table S

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

```
SELECT *
FROM SP
WHERE PId='P2' AND
        SP.SId='S1'
```

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

- The predicate including NOT EXISTS is false for S1 since there exists a supply for P2 by F1
  - S1 *does not* belong to the result of the query

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

- The predicate including NOT EXISTS is true of S4 since there exists no supply for P2 by S4
  - S4 belongs to the result of the query

How NOT EXISTS works (no.1)

- Find the names of the suppliers that *do not* supply product P2

S

SId	SName	#Employees	City
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens

SP

SId	PId	Qty
S1	P1	300
S1	P2	200
S1	P3	400
S1	P4	200
S1	P5	100
S1	P6	100
S2	P1	300
S2	P2	400
S3	P2	200
S4	P3	200
S4	P4	300
S4	P5	400

Result of the query (no.1)

- Find the names of the suppliers that *do not* supply product P2

R

SName
Clark
Adams

Predicates with NOT EXISTS

- The predicate including NOT EXISTS is
  - true if the inner query returns the empty set
  - false if the inner query return at least one tuple
- The correlation condition binds the execution of the inner query to the values of attributes of the current tuple in the outer query

Nested queries

Correlation among queries

Correlation among queries

- It may be required to bind the computation of a nested query to the value(s) of one or more attributes in an outer query
  - the binding is expressed by one or more correlation conditions

Correlation condition

- A correlation condition
  - must be specified in the WHERE clause of the nested query that requires it
  - is a predicate that binds some attributes of tables appearing in the nested query's FROM clause to attributes of tables appearing in the FROM clause of outer queries
- Correlation conditions may not be expressed
  - within queries at the same nesting level
  - with references to attributes of a table appearing in the FROM clause of a nested query

Correlation among queries (no.1)

- For each product, find the code of the supplier that provides the highest quantity

Correlation among queries (no.1)

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT PId, SId
FROM SP AS SPX
WHERE Qty = (...
)
```

Maximum quantity for the current product

Correlation among queries (no.1)

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT PId, SId
FROM SP AS SPX
WHERE Qty = (SELECT MAX(Qty)
             FROM SP AS SPY
             ...                )
```

Maximum quantity

Correlation among queries (no.1)

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT PId, SId
FROM SP AS SPX
WHERE Qty = (SELECT MAX(Qty)
             FROM SP AS SPY
             WHERE SPY.PId=SPX.PId);
```

Maximum quantity for the current product

Correlation among queries (no.1)

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT PId, SId
FROM SP AS SPX
WHERE Qty = (SELECT MAX(Qty)
             FROM SP AS SPY
             WHERE SPY.PId=SPX.PId);
```

Correlation condition

Correlation among queries (no.1) – Alternative solution

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT Sid
FROM SP AS SPX
WHERE (PID, QTY) IN (SELECT PID, Max(Qty)
                     FROM SP
                     GROUP BY PID)
```

Correlation among queries (no.1) – Wrong solution

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT Sid
FROM SP AS SPX
WHERE QTY = (SELECT Max(Qty)
             FROM SP
             GROUP BY PID)
```

Correlation among queries (no.1) – Wrong solution

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT Sid
FROM SP AS SPX
WHERE QTY = (SELECT Max(Qty)
             FROM SP)
```

Correlation among queries (no.1) – Wrong solution

- For each product, find the code of the supplier that provides the highest quantity

```
SELECT Sid
FROM SP AS SPX
WHERE QTY = (SELECT Max(Qty)
             FROM SP SPY
             WHERE SPY.PID=SPX.PID
             GROUP BY PID)
```

Correlation among queries (no.2)

TRIP (TId, StartingPlace, Destination,
DepartureTime, ArrivalTime)

- Find the codes of the trips whose duration is lower than the average duration of the trips on the same route (i.e., same starting place and destination)

```
SELECT TId
FROM TRIP AS TA
WHERE ArrivalTime-DepartureTime < (...
)
```

Average duration of trips on the current route

Correlation among queries (no.2)

TRIP (TId, StartingPlace, Destination,
DepartureTime, ArrivalTime)

- Find the codes of the trips whose duration is lower than the average duration of the trips on the same route (i.e., same starting place and destination)

```
SELECT TId
FROM TRIP AS TA
WHERE ArrivalTime-DepartureTime <
        (SELECT AVG(ArrivalTime-DepartureTime)
         FROM  TRIP AS TB
         ...        )
```

Average duration of trips

Correlation among queries (no.2)

TRIP (TId, StartingPlace, Destination,
DepartureTime, ArrivalTime)

- Find the codes of the trips whose duration is lower than the average duration of the trips on the same route (i.e., same starting place and destination)

```
SELECT TId
FROM TRIP AS TA
WHERE ArrivalTime-DepartureTime <
        (SELECT AVG(ArrivalTime-DepartureTime)
         FROM  TRIP AS TB
         WHERE TB.StartingPlace=TA.StartingPlace
               AND TB.Destination=TA.Destination);
```

Correlation conditions

Nested queries

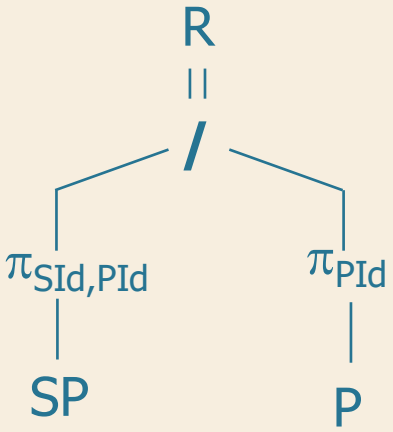
The division operation

The division operation (no.1)

- Find the codes of the suppliers that supply *all* products
- In relational algebra we must use the division operator

The division operation (no.1)

- Find the codes of the suppliers that supply *all* products
- In relational algebra we must use the division operator



Division in SQL (no.1)

- Find the codes of the suppliers that supply *all* products

- Remark
  - all products that may be supplied are listed in table P

  - a supplier is supplying all products if he is supplying a number of distinct products equal to the cardinality of P

Division in SQL (no.1)

- Find the codes of the suppliers that supply *all* products

```
SELECT COUNT(*)
FROM P
```

Division in SQL (no.1)

- Find the codes of the suppliers that supply *all* products

```
SELECT COUNT(*)
FROM P
```

Total number of products

Division in SQL (no.1)

- Find the codes of the suppliers that supply *all* products

```
SELECT SId
FROM SP
GROUP BY SId
…                          (SELECT COUNT(*)
                            FROM P)
```

Division in SQL (no.1)

- Find the codes of the suppliers that supply *all* products

SP(SID, PID, Qty)

```
SELECT SId
FROM SP
GROUP BY SId
HAVING COUNT(*)=(SELECT COUNT(*)
                 FROM P);
```

Division in SQL (no.1) – Different SP TABLE

- Find the codes of the suppliers that supply *all* products

SP(SID, PID, Date, Qty)

```
SELECT SId
FROM SP
GROUP BY SId
HAVING COUNT(DISTINCT PID)=(SELECT COUNT(*)
                           FROM P);
```

Division in SQL: procedure (no.2)

- Find the codes of the suppliers that supply at least *all* of the products supplied by supplier S2
- We must count
  - the number of products supplied by S2
  - the number of products supplied both by an arbitrary supplier and by S2
    - (Alternative formulation)
    - Among the products supplied by S2, count the number of products supplied by an arbitrary supplier
- The two counts must be equal

Division in SQL (no.2)

- Find the codes of the suppliers that supply at least *all* of the products supplied by supplier S2

```
SELECT COUNT(*)
FROM SP
WHERE SId='S2'
```

Division in SQL (no.2)

- Find the codes of the suppliers that supply at least *all* of the products supplied by supplier S2

```
SELECT COUNT(*)
FROM SP
WHERE SId='S2'
```

Number of products supplied by S2

Division in SQL (no.2)

- Find the codes of the suppliers that supply at least *all* of the products supplied by supplier S2

```
SELECT SId
FROM SP
WHERE PId IN (SELECT PId
                    FROM SP
                    WHERE SId='S2')
GROUP BY SId
...                         (SELECT COUNT(*)
                             FROM SP
                             WHERE SId='S2')
```

Division in SQL (no.2)

- Find the codes of the suppliers that supply at least *all* of the products supplied by supplier S2

```
SELECT SId
FROM SP
WHERE PId IN (SELECT PId
              FROM SP
              WHERE SId='S2')
GROUP BY SId
HAVING COUNT(*)=(SELECT COUNT(*)
                 FROM SP
                 WHERE SId='S2');
```

Nested queries

Table functions

Example schema

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)
COURSE (CId, CName)

Computing two-level aggregates (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)

- 2-step solution
  - find the average for each student
  - find the maximum average value

Computing two-level aggregates (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)
  - step 1: average for each student

```
SELECT SId, AVG(Grade) AS StudentAVG
FROM  PASSED-EXAM
GROUP BY SId
```

Computing two-level aggregates (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)
  - step 1: average for each student

```
(SELECT SId, AVG(Grade) AS StudentAVG
FROM  PASSED-EXAM
GROUP BY SId) AS AVERAGES
```

Computing two-level aggregates (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)
  - step 2: maximum average value

```
SELECT ...
FROM (SELECT SId, AVG(Grade) AS StudentAVG
      FROM  PASSED-EXAM
      GROUP BY SId) AS AVERAGES
```

Computing two-level aggregates (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)
  - step 2: maximum average value

```
SELECT MAX(StudentAVG)
FROM (SELECT SId, AVG(Grade) AS StudentAVG
        FROM  PASSED-EXAM
        GROUP BY SId) AS AVERAGES;
```

Table functions (no.1)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- Find the highest average (achieved by a student)

```
SELECT MAX(StudentAVG)
FROM (SELECT SId, AVG(Grade) AS StudentAVG
      FROM  PASSED-EXAM
      GROUP BY SId) AS AVERAGES;
```

Table function

Table function

- It defines a temporary table that may be used for further computations
- The table function
  - has the structure of a SELECT statement
  - is defined within a FROM clause
  - may be referenced as a normal table
- Table functions allow
  - the computation of multi-level aggregates
  - an equivalent formulation of queries that require the use of correlation

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
- 2-step solution
  - find the average for each student
  - group students by year of enrolment and compute the maximum average

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
  - step 1

```
(SELECT SId, AVG(Grade) AS StudentAVG
 FROM  PASSED-EXAM
 GROUP BY SId) AS AVERAGES
```

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
  - step 2

```
SELECT ...
FROM STUDENT,
     (SELECT SId, AVG(Grade) AS StudentAVG
      FROM  PASSED-EXAM
      GROUP BY SId) AS AVERAGES
WHERE STUDENT.SId=AVERAGES.SId
...
```

Table function

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
  - step 2

```
SELECT ...
FROM STUDENT,
        (SELECT SId, AVG(Grade) AS StudentAVG
         FROM  PASSED-EXAM
         GROUP BY SId) AS AVERAGES
WHERE STUDENT.SId=AVERAGES.SId
...
```

Join condition

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
  - step 2

```
SELECT ...
FROM STUDENT,
        (SELECT SId, AVG(Grade) AS StudentAVG
         FROM  PASSED-EXAM
         GROUP BY SId) AS AVERAGES
WHERE STUDENT.SId=AVERAGES.SId
GROUP BY YearOfEnrolment
```

Table functions (no.2)

STUDENT (SId, YearOfEnrolment)
PASSED-EXAM (SId, CId, Date, Grade)

- For each year of enrolment, find the highest average (achieved by a student)
  - step 2

```
SELECT YearOfEnrolment, MAX(StudentAVG)
FROM STUDENT,
        (SELECT SId, AVG(Grade) AS StudentAVG
         FROM  PASSED-EXAM
         GROUP BY SId) AS AVERAGES
WHERE STUDENT.SId=AVERAGES.SId
GROUP BY YearOfEnrolment;
```