Relational Model and Algebra

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Relations are sets of typed tuples

Relations

Relations take the form $R(A, B, \ldots)$ where

- R is the name of the relation
- $A, B, \ldots$
  - a
  - et of
  - $Domain(A)$ is the set of values (type) that the attribut
  - Will use $Atts(R)$ to find $A, B, \ldots$
- The **extent** of $R(A, B, \ldots)$ is the set of **tu**

$$\{\langle v_1^A, v_1^B, \ldots\rangle, \langle v_2^A, v_2^B, \ldots\rangle, \langle v_3^A, v_3^B, \ldots\rangle, \ldots$$

  - $\forall x.v_x^A \in Domain(A)$
  - No duplicate tuples
  - Not ordered
  - All tuples have the same arity

Relation=Table

R		
A	B	$\ldots$
$\vdots$		

Set Semantics

- Attribute=Column
- Tuple=Row

Quiz 1: Equivalent Relations

Which is the odd one out?

A

branch
sortcode
56
34
67

B

branch
cash
94340.45
8900.67
34005.00

C

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

D

sor		ash
56	'Wimbledon'	94340.45
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

Handling 'missing' attribute values

Suppose we want to have a relation account(no,type,cname,rate,sortcode), but not all accounts have a rate.

Solution 1: Separate relations

account

no	type	cname	sortcode
100	'cu		
101	'de		
103	'cu		
107	'cu		
119	'de		
125	'current'	'Bailey, J.'	56

Solution 2: NULL values

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

Relational Keys

Key

A **key** of a relation $R(AB\ldots)$ is a subset of the attributes for which the values in any extent are unique across all tuples

- Ever utes
- A key is values for the attributes of the key
- If A is a key, then so must AB be a key
- A **minimal key** is a set of attributes $AB\ldots$ such that no subset of the attributes is also a key

- The **primary key** is one of the keys of the relation: serves as the default key when no key explicitly stated

Quiz 2: Violation of Relational Keys

movement			
mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	5/1/1999
1004	107	-100.00	11/1/1999

Which key is violated?

A

movement(mid)

B

movement(no,amount)

C

movement(no,tdate)

D

movement(amount,tdate)

Quiz 3: Correct Keys for Relations

movement			
mid	no	amount	tdate
1000	100	2300.00	5/1/1999
1001	101	4000.00	5/1/1999
1002	100	-223.45	5/1/1999
1004	107	-100.00	11/1/1999

Which key makes most sense in a bank UoD?

A

movement(amount)

B

movement(no,amount)

C

movement(no,tdate)

D

movement(amount,tdate)

Relational Foreign Keys

Foreign Key

A **foreign key** $R(\vec{X}) \overset{fk}{\Rightarrow} S(\vec{Y})$ of a relation $R(AB\ldots)$ is a subset $\vec{X} \subseteq AB\ldots$ of the attributes for which the values in the extent of R also appear as values of attributes $\vec{Y}$ in the exte

account(s

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

		cash
		94340.45
		8900.67
67	'Strand'	34005.00

Quiz 4: Foreign Key Violation

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

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	'cur			
119	'dep			
125	'cur			

key branch(sortcode)

branch

sortcode	bname	cash
56	'Wimbledon'	94340.45
		8900.67
		34005.00

Which update violates the foreign key?

A

insert into account
(126,'business','McBrien, P.',1.00,67)

B

inser i
(78,'Ealing',1000.00)

C

delete from branch
(67,'Strand',34005.00)

D

delete from account
(103,'current','Boyd, M.',NULL,34)

Example Relational Schema

branch

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

account

no	type	cname	rate	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
			LL	34
			LL	56
			50	56
			L-	56

mid	no		
1000	100		
1001	101	4000.00	5/1/1999
1002	100	-223.45	8/1/1999
1004	107	-100.00	11/1/1999
1005	103	245.50	12/1/1999
1006	100	15.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

key branch(so
key branch(b
key movemer
key account(n

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

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

Relational Algebra: A Query Language for the Relational Model

Primitive operators of the Relational Algebra

Symbol	Name	Type
−	Difference	Binary

- All operators take relations as input
- All operators produce one relation as their output
- Other (useful) operators may be defined in terms of the five primitive operators

Relational Algebra: Project π

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

Project Op

$\pi_{no,type}$ account

no	type
100	'current'
101	'deposit'
103	'current'
107	'current'
119	'deposit'
125	'current'

$\pi_{sortcode}$ account

sortcode
67
34
56

Relational Algebra: Select σ

account

no	type	cname	rate	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67

Select Operator

$\sigma_{rate>0}(account)$

no	type	cname	rate	sor
101	'deposit'	'McBrien, P.'	5.25	
119	'deposit'	'Poulovassilis, A.'	5.50	56

Relational Algebra: Product ×

branch

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

$\sigma_{rate>0}$(account)

no	type	cname	rate	sortcode
101	'deposit'	'McBrien, P.'	5.25	67
119	'deposit'	'Poulovassilis, A.'	5.50	56

Product C

sortcode	bname	cash	no	type	cname	rate	sortcode
56	'Wimbledon'	94340.45	101	'deposit'	'McB		
56	'Wimbledon'	94340.45	119	'deposit'	'Poul		
34	'Goodge St'	8900.67	101	'deposit'	'McB		
34	'Goodge St'	8900.67	119	'deposit'	'Poul		
67	'Strand'	34005.00	101	'deposit'	'McB		
67	'Strand'	34005.00	119	'deposit'	'Poulovassilis, A.'	5.50	56

Quiz 5: RA Queries

branch

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

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
			.50	56
			LL	56

Which RA q ts?

A

$\pi_{\text{sortcode}}\, \sigma_{\text{type}=\text{'deposit'}}\, \text{account}$

B

π_{bnam}
σ_{accou} osit'
$(\text{account} \times \text{branch})$

C

$\pi_{\text{bname}}(\text{branch} \times \sigma_{\text{type}=\text{'deposit'}}\, \text{account})$

D

$\pi_{\text{bname}}\, \sigma_{\text{type}=\text{'deposit'}}(\text{account} \times \text{branch})$

SPJ Queries

Select Project Join (SPJ) queries

If a product of tables is formed, where a selection is then done that compares the attributes of those tables, we say that a **join** has been performed.

Normally n ject is also required.

Branches

$\pi_{\text{bname,no}}\, \sigma_{\text{branch.sortcode}=\text{account.sortcode} \wedge \text{account.type}=\text{`curr}$

bname	
'Goodge St'	
'Wimbledon'	
'Wimbledon'	125
'Strand'	100

Relational Algebra: Union ∪

$\pi_{\text{sortcode as id}}$account

id
67
34
56

$\pi_{\text{no as id}}$account

id
100
101

Union Operator

$\pi_{\text{sortcode as id}}$account ∪ $\pi_{\text{no as id}}$account

id
67
34
56
100
101
103
107
119
125

- relations must be **union compatible**

Relational Algebra: Difference –

π_{no}account

no
100
101

π_{no}movement

no
100
101

Difference Operator

π_{no}account – π_{no}movement

no
125

- relations must be **union compatible**

Rules for Combining Operators

Since all operators produce a relation as output, *any* operator may produce one of the inputs to a

well forme

- the out ed by an outer π or σ
- the two inputs to a $\cup$ or $-$ must contain the sa

Quiz 6: Well formed queries

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	'curr			
119	'dep			
125	'curr			

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
			12/1/1999
			15/1/1999
			15/1/1999
			15/1/1999
			18/1/1999

Which RA query is well formed?

A

$\sigma_{\text{type}=\text{'current'}}\ \pi_{\text{no}}$ account

B

π_{no} account $-\ \pi_{\text{no,mid}}$ movement

C

$\pi_{\text{no}}\ \sigma_{\text{type}=\text{'current'}}$ account

D

$\pi_{\text{no}}\ \pi_{\text{type}}$ account

Worksheet: Primitive Relational Algebra Operators

branch

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

account

no	type	cname	rate	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
			LL	34
			LL	56
			50	56
			L-	56

mid	no		
1000	100		
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	15.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

key branch(so
key branch(b
key movemer
key account(n

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

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

Derived Relational Algebra: Natural Join ⋈

Natural Join

$$R \bowtie S = \sigma_{R.A_1=S.A_1 \wedge \ldots \wedge R.A_m=S.A_m} R \times S$$

Natural Jo

rtt

⋈

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

Quiz 7: Natural Join

What is the result of π_{no}(account ⋈ movement)?

A

π_{no}(accou

101
103
107
119
125

C

π_{no}(account ⋈ movement)
no
125

D

π_{no}(account ⋈ movement)
no

Derived Relational Algebra: Semi Join ⋉

Semi Join

$$R \ltimes S = R \bowtie \pi_{Attr(R) \cap Attr(S)}(S)$$

Semi Join

account ⋉ movement

no	type	cname		
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

Derived Relational Algebra: Joins

Natural Join

$$R \bowtie S = \sigma_{R.A_1=S.A_1 \wedge \ldots \wedge R.A_m=S.A_m} R \times S$$

Equi Join

Semi Join

$$R \ltimes S = R \bowtie \pi_{Attr(R)}$$

Theta Join

$$R \overset{\theta}{\bowtie} S = \sigma_\theta R \times S$$

Quiz 8: Understanding join operators

branch

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

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
			.50	56
			LL	56

Which RA q

A

$\text{branch} \overset{\text{branch.sortcode=account.sortcode}}{\bowtie} \text{account}$

B

branch

C

$\text{branch} \ltimes \text{account}$

D

$\text{branch} \overset{\text{branch.sortcode=account.sortcode}}{\bowtie} \text{account}$

Quiz 9: Foreign Keys and Natural Joins (1)

Suppose R and S only share attribute A, and there is a foreign key $S(A) \stackrel{fk}{\Rightarrow} R(A)$.

If $|R| = 10$

A

100

1,000

C

100,000

D

900

Note that $|R|$ returns the number of tuples in the current ex

Quiz 10: Foreign Keys and Natural Joins (2)

Suppose R and S only share attribute A, and there is a foreign key $R(A) \overset{fk}{\Rightarrow} S(A)$.

If $|R| = 10$

A

100

1,000

C

100,000

D

900

Derived Relational Algebra: Intersection ∩

Intersection

$$R \cap S = R - (R - S)$$

π_{no}accou

π_{no}accou

n
100
101
103
107
119
125

π_{no}account − π_{no}movement

no
125

t

no

Quiz 11: Intersection

email	
name	address
'McBrien, P.'	p.mcbrien@imperial.ac.uk
'Poulovassilis, A.'	ap@dcs.bbk.ac.uk
'Pietzuch, P.'	prp@doc.ic.ac.uk

What is the result of π account $\cap$ π email?

A

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

'Mc
'Bo
'Po
'Bai

C

cname
'McBrien, P.'
'Poulovassilis, A.'
'Pietzuch, P.'

D

cname
'McBrien, P.'
'Poulovassilis, A.'

Derived Relational Algebra: Division ÷

Division

$$R \div S = \pi_{Atts(R)-Atts(S)}(R) - \pi_{Atts(R)-Atts(S)}((\pi_{Atts(R)-Atts(S)}(R) \times S) - R)$$

Division

$\pi_{\text{cname,type}}$ account $\div$ π_{type} account

$\pi_{\text{cname,type}}$ account $\div$ π_{type} account

$\pi_{\text{cname}}((\pi_{\text{cname}}\,\text{account} \times \pi_{\text{type}}\,\text{account}) - \pi_{\text{cname,type}}\,\text{account})$

$\pi_{\text{cname,type}}$ account

cname	type
'McBrien, P.'	'current'
'McBrien, P.'	'deposit'
'Boyd, M.'	'current'
'Poulovassilis, A.'	'current'
'Poulovassilis, A.'	'deposit'
'Bailey, J.'	'current'

π_{type} account

type
'current'
'deposit'

count

cname
'McBrien, P.'
'Poulovassilis, A.'

Evaluation of Division

π_{cname} account

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

π_{type} account

type
'current'
'deposit'

'McBrien, P.'	'current'
'McBrien, P.'	
'Boyd, M.'	
'Boyd, M.'	
'Poulovassilis, A.'	
'Poulovassilis, A.'	
'Bailey, J.'	'current'
'Bailey, J.'	'deposit'

Evaluation of Division

π_{cname} account $\times$ π_{type} account

cname	type
'McBrien, P.'	'current'
'McBrien, P.'	'deposit'
'Boyd, M.'	'current'
'Boyd, M.'	'deposit'

$\pi_{cname,type}$ account

cname	type
'McBrien, P.'	'current'
'McBrien, P.'	'deposit'
'Boyd, M.'	'current'

$\Downarrow$

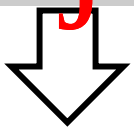
(π_{cname} account $\times$ π_{type} account)

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

Evaluation of Division

$(\pi_{\text{cname}}\ \text{account} \times \pi_{\text{type}}\ \text{account}) - \pi_{\text{cname,type}}\ \text{account}$

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



Evaluation of Division

π_{cname} account

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

$\pi_{\text{cname}}((\pi_{\text{cname}}\ \text{account} \times \pi_{\text{type}}\ \text{account}) - \pi_{\text{cname,type}}\ \text{account})$

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

π_{c} account)

cn
'McBrien, P.'
'Poulovassilis, A.

Worksheet: Derived Relational Algebra Operators

branch

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

account

no	type	cname	rate	sortcode
100	'current'	'McBrien, P.'	NULL	67
101	'deposit'	'McBrien, P.'	5.25	67
			LL	34
			LL	56
			50	56
			L	56

mid	no		
1000	100		
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	15.23	15/1/1999
1007	107	345.56	15/1/1999
1008	101	1230.00	15/1/1999
1009	119	5600.00	18/1/1999

key branch(so
key branch(b
key movemen
key account(n

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

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

Equivalences Involving Project

Project and Project

$\pi_{\vec{X}}\, \pi_{\vec{Y}}\, R \equiv \pi_{\vec{X}}\, R$

You can eliminate any inner project (note that to be well formed $\vec{X} \subseteq \vec{Y}$)

Project and Select

$\pi_{\vec{X}}\, \sigma_{P(\vec{Y})}\, R$

You can mo ication
can be ans we

Project and Product

$\pi_{\vec{X}}(R \times S) \equiv \pi_{\vec{X} \cap Atts(R)}\, R \times \pi_{\vec{X} \cap Atts(S)}\, S$

Project and Union

$\pi_{\vec{X}}(R \cup S) \equiv \pi_{\vec{X}}\, R \cup \pi_{\vec{X}}\, S$

Project and Difference

$\pi_{\vec{X}}(R - S) \supseteq \pi_{\vec{X}}\, R - \pi_{\vec{X}}\, S$

Equivalences Involving Select

Select and Project

$$\sigma_{P(\vec{X})}\, \pi_{\vec{X}}\, R \equiv \pi_{\vec{X}}\, \sigma_{P(\vec{X})}\, R$$

Select and Select

$$\sigma_{P_x(\vec{X})}\, \sigma_{P_y(\vec{Y})}\, R \equiv \sigma_{P\ (\vec{X}) \wedge P\ (\vec{Y})}\, R$$

Select and P

$$\sigma_{P(\vec{X})}(R \times \qquad_{P(X)}$$

You can move a select predicate $P(\vec{X})$ onto one of the re

provided $\vec{X} \subseteq \text{Atts}(R)$

Select and Union

$$\sigma_{P(\vec{X})}(R \cup S) \equiv \sigma_{P(\vec{X})}\, R \cup \sigma_{P(\vec{X})}\, S$$

Select and Difference

$$\sigma_{P(\vec{X})}(R - S) \equiv \sigma_{P(\vec{X})}\, R - S$$

Quiz 12: Equivalent RA Expressions (Unary Operators)

Which RA expression is not equivalent to the other three?

A

$\pi_{\text{no}}\ \sigma_{\text{type}=\text{'c}$

ccount

C

$\pi_{\text{no}}\ \sigma_{\text{type}<>\text{'deposit'}}\ \pi_{\text{no,type,cname}}$ account

D

$\pi_{\text{no}}\ \sigma$ nt

Quiz 13: Query Evaluation

Which RA means that the $\times$ operator handles fewer tuples?

A

$\sigma_{\text{account.no}=}$
$(\sigma_{\text{sortcode}=6}$

$_{7}$
nt)

C

$\sigma_{\text{account.no}=\text{movement.no} \wedge \text{amount}<0}$
$(\sigma_{\text{sortcode}=67}$ account $\times$ movement$)$

D

$(\sigma_{\text{accou}}$ $_{\text{unt}<0}$
(acco

Equivalences Involving Binary Operators

Product and Union

$R \times (S \cup T) \equiv (R \times S) \cup (R \times T)$

Product and Difference

$R \times (S - T) \equiv (R \times S) - (R \times T)$

Union and

$R \cup (S \times$

Union and Difference

$R \cup (S - T)$ unable to move $\cup$ inside $-$

Difference and Product

$R - (S \times T)$ unable to move $-$ inside $\times$

Difference and Union

$R - (S \cup T) \equiv (R - S) - T$

Quiz 14: Equivalent RA Expressions (Binary Operators)

Which equivalence does not hold?

A

$(R \times S) \times$

C

$(R \cup S) \cup T \equiv R \cup (S \cup T)$

D

$R \cap$

Worksheet: Equivalences Between RA Expressions

1. $\pi_{\text{no,typ}}$
2. σ_{accoun}
3. σ_{accoun} $\left(\sigma_{\text{amount}>1000}\ \pi_{\text{mid,no}}\ \text{movement} \cup \sigma_{\text{amoun}}\right.$
4. $\pi_{\text{no,cname,tdate}}\ \sigma_{\text{amount}<0 \wedge \text{account.no}=\text{movement.no}}\ \text{acc}$

Quiz 15: Monotonic and non-monotonic operators

A monotonic operator has the property that an additional tuple put into any input relation which only cause additional tuples to be generated in the output relation.

A non-monotonic operator has the property that an additional tuple put into an input relati

Which RA o

A

π R

B

R×

C

R ∪ S

D

R − S

Incremental Query Evaluation

Suppose we add rows Δ_R to extent of relation R so it becomes R'

If we represent Δ_R as a relation (with the same attributes as R) then

$R' = R \cup$

$\pi_{\vec{X}} R' \equiv \pi$

$\sigma_{P(\vec{X})} R'$

$R' \times S \equiv (R \times S) \cup (\Delta_R \times S)$

$R' \cup S \equiv (R \cup S) \cup \Delta_R$

$R' - S \equiv (R - S) \cup (\Delta_R - S)$

$S - R' \equiv (S - R) - \Delta_R$

Example: Query result after update to account (1)

1. Suppose that we had already evaluated query Q
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{account.type='current'}}(\text{branch} \times \text{account})$

bname	no
'Goodge St'	103
'Wi	7
'Wi	5
'Stra	0

2. If Δ_a
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{account.type='current'}}(\text{branch} \times \text{account}')$
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{account.type='}}$ anch $\times$ $\Delta_{\text{account}}))$
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{account.type='}}$
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{accou}}$ t)

3. Thus if $\Delta_{account}$ is added to account, we only need evaluate
   $\pi_{\text{bname,no}}\sigma_{\text{branch.sortcode=account.sortcode}\wedge\text{account.type='current'}}(\text{branch} \times \Delta_{\text{account}})$

Example: Query result after update to account (2)

4. Suppose we have

$\Delta_{account}$

126	'business'	'McBrien, P.'	1.00	67
127	'current'	'Pietzuch, P.'	NULL	34

Then

π_{bna} ... nt)

bna	rd
'Goo	27

5. Thus since $Q' = Q \cup \Delta_Q$

$\pi_{\text{bname,no}}\ \sigma_{\text{branch.sortcode=account.sortcode} \wedge \text{account.type}}$

bname	
'Goodge St'	
'Wimbledon'	
'Wimbledon'	125
'Strand'	100
'Goodge St'	127