Primitive RA Operators

			SQL DML
π	Project (order does not matter)	(1)	SELECT DISTINCT (SELECT returns a bag, π returns a set)
σ	Select	(1)	WHERE
$\times$	Cartesian Product	(2)	CROSS JOIN
$\cup$	Union *	(2)	UNION
$-$	Difference *	(2)	EXCEPT (ALL for bag)

* must be union compatible
- same no. of attributes
- domain of attributes must be compatible

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
$\pi_{\vec{X}} \sigma_{P(\vec{Y})} R \equiv \sigma_{P(\vec{Y})} \pi_{\vec{X}} R$
If $\vec{Y} \subseteq \vec{X}$ you can move a project of $\vec{X}$ inside a select of $\vec{Y}$

Project and Product
$\pi_{\vec{X}}(R \times S) \equiv \pi_{\vec{X} \cap Attrs(R)} R \times \pi_{\vec{X} \cap Attrs(S)} S$

Project and Union
$\pi_{\vec{X}}(R \cup S) \equiv \pi_{\vec{X}} R \cup \pi_{\vec{X}} S$

Project and Difference
$\pi_{\vec{X}}(R - S) \supseteq \pi_{\vec{X}} R - \pi_{\vec{X}} S$

Select and Project
$\sigma_{P(\vec{X})} \pi_{\vec{X}} R \equiv \pi_{\vec{X}} \sigma_{P(\vec{X})} R$

Select and Select
$\sigma_{P_x(\vec{X})} \sigma_{P_y(\vec{Y})} R \equiv \sigma_{P_x(\vec{X}) \wedge P_y(\vec{Y})} R$

Select and Product
$\sigma_{P(\vec{X})}(R \times S) \equiv \sigma_{P(\vec{X})} R \times S \iff \vec{X} \subseteq Attrs(R)$
If $\vec{X} \subseteq Attrs(R)$ you can move a select predicate $P(\vec{X})$ onto 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
$\sigma_{P(\vec{X})}(R - S) \equiv \sigma_{P(\vec{X})} R - S$

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

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

Derived RA Operators (2)

			SQL DML
$\bowtie$	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 JOIN
$\ltimes$	Semi Join	$R \ltimes S = R \bowtie \pi_{Attr(R) \cap Attr(S)} S$	
$\cap$	Intersection *	$R \cap S = R - (R - S)$	INTERSECT (ALL for bag)
$\div$	Division	$R \div S = \pi_{Attr(R)-Attr(S)} R - \pi_{Attr(R)-Attr(S)}((\pi_{Attr(R)-Attr(S)} R \times S) - R)$	
$\overset{A=B}{\bowtie}$	Equi Join	$R \overset{A=B}{\bowtie} S = \sigma_{R.A=S.B} R \times S$	JOIN .. ON
$\overset{\theta}{\bowtie}$	Theta Join	$R \overset{\theta}{\bowtie} S = \sigma_{\theta} R \times S$	JOIN .. ON

SELECT DISTINCT x FROM t AS t_1
WHERE NOT EXISTS (SELECT y FROM t
EXCEPT SELECT y FROM t WHERE t.x = t_1.x) } $x \div y$

↳ project the extra attributes in R that have each of the attributes of S

$\pi_{cname,type}$ 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'

$\pi_{cname,type}$ account $\div$ π_{type} account
cname
'McBrien, P.'
'Poulovassilis, A.'

SQL Set Operations

WHERE x IN y

- IN — WHERE no IN (100, 101) — listed produced
- EXIST — WHERE NOT EXIST (SELECT...) — produced
- ALL — WHERE '11-jan-1999' < ALL (SELECT...) — produced
- SOME — WHERE 'deposit' = SOME(SELECT...) — produced

SQL Null

nulls are combined in SETS

- x=null, null=null gives UNKNOWN
- x IS NULL, x IS NOT NULL gives TRUE/FALSE
- NOT IN (null, ...) always returns nothing!
- NOT EXIST(SELECT ....=null) always returns everything!

SQL Joins

LEFT/RIGHT JOIN $\overset{L/R}{\bowtie}$ returns every row in left/right even if no row matches, filled with NULL instead

OUTER JOIN $\overset{o}{\bowtie}$ returns LEFT JOIN ∪ RIGHT JOIN — FULL OUTER JOIN IN SQL

SQL Extensions

- _ for single char
- % for any char
- [A-C] for single A to C
- [ABC] for single ABC

Pattern Matching: WHERE column LIKE pattern ESCAPE escape_char

Cases: , CASE
WHEN ~
THEN ~
⋮
(ELSE ~) optional
END AS ~,

Modifications: ROUND(n, dp), SUBSTRING(str FROM n_1 FOR n_2),
(must be placed in SELECT clause) UPPER(str), CHAR_LENGTH(str), POSITION(char IN str)

Aggregate: SUM, COUNT, AVG, MIN, MAX excludes NULL

COALESCE(a, b, c) goes down list until non-null

SQL OLAP

GROUP BY : only one output per group, aggregate functions for non grouped columns. NULL is grouped together

HAVING: similar to WHERE but for aggregates (SELECT.... FROM... WHERE... GROUP BY .... HAVING)

PARTITION: one output per row, AVG(x) OVER (PARTITION BY y) ....

ORDER BY ... DESC : default ascending, RANK() OVER (ORDER BY ...) for numbering.

DATALOG Head :- Body

1. If Body then Head.
2. Head is a single pred
3. Body is a conjunction of pred

a. cannot use same name for intentional (head) & extensional (body) preds.

b. preds start with small letter, vars start with capital letter

c. _ can be used for var that only appears once

Safe negation: A var in a negated ¬ pred must also appear in a non-negated pred.

π : use subset of body vars in head

σ : use variable more than once / with data value

×: name two preds in rule body

⋈ : name two preds in rule body, with same name / compare attribute

U: more than one rule def for intentional pred

− : negation on pred being subtracted

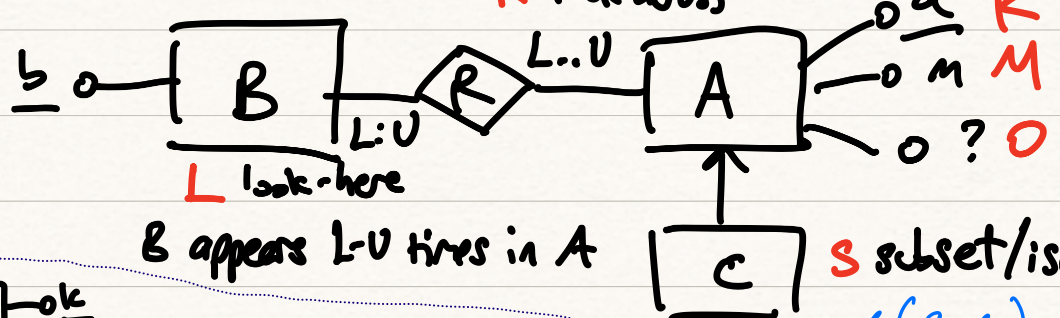
ER Modelling

$1:1 - 0:N$, $A(\ldots, b)$ $A(b) \xrightarrow{FK} B(b)$
$0:1 - 0:N$, $A(\ldots, b?)$ $A(b) \xrightarrow{FK} B(b)$
$0:N - 0:N$, $R(\underline{a}, \underline{b})$ $R(a) \xrightarrow{FK} A(a)$ $R(b) \xrightarrow{FK} B(b)$

B appears L-U times in A

K look across

$A(\underline{a}, m, o?)$



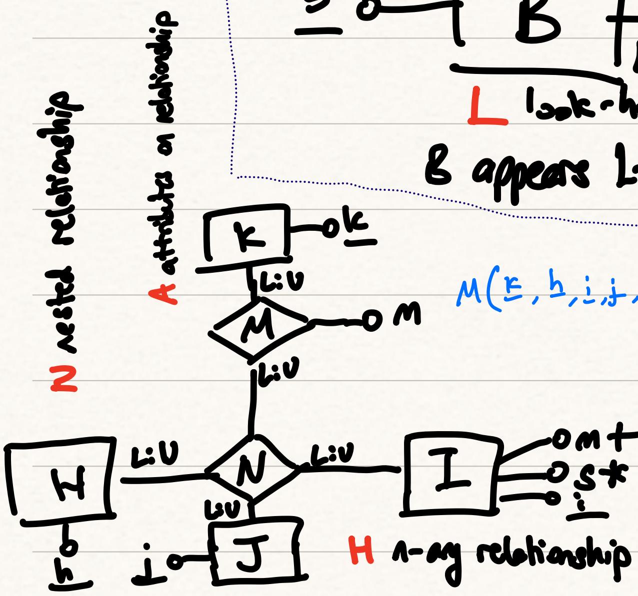
K key
M mandatory
O optional

L look-here

B appears L-U times in A

S subset/isa hierachy

$C(\underline{a}, c)$ $C(a) \xrightarrow{FK} A(a)$



$M(\underline{k}, \underline{h}, \underline{i}, \underline{j}, m)$ $M(k) \xrightarrow{FK} K(k)$
$M(h,i,j) \xrightarrow{FK} N(h,i,j)$

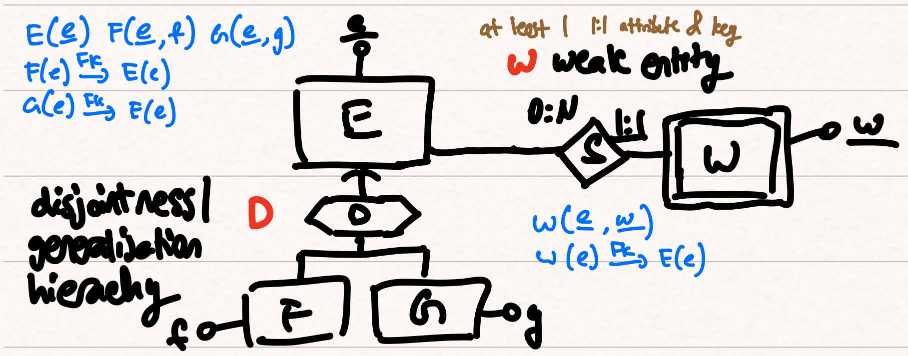
V multi-valued
optional + multivalued

H n-ary relationship

$I(\underline{i})$
$IM(\underline{i}, \underline{m})$ $IM(i) \xrightarrow{FK} I(i)$
$IS(\underline{i}, \underline{s})$ $IS(i) \xrightarrow{FK} I(i)$
* and + same
all key

many-many, $N(\underline{h}, \underline{i}, \underline{j})$ 3xFK all key
one-many from H, $H(\underline{h}, \underline{i}, \underline{j})$ 2xFK

$E(\underline{e})$ $F(\underline{e}, f)$ $G(\underline{e}, g)$
$F(e) \xrightarrow{FK} E(e)$
$G(e) \xrightarrow{FK} E(e)$



at least 1 1:1 attribute & key
W weak entity

disjointness/generalisation hierachy **D**

$W(\underline{e}, \underline{w})$
$W(e) \xrightarrow{FK} E(e)$

Keys & FDs

Generate minimal keys: 1. Generate minimal cover
2. Find keys where $K^+ = Attr(R)$

Super-key X of R: X determines all other attributes of R

(non-unique) **minimal-key** X of R: not possible to remove attributes to form another super-key.

closure S^+: all FDs that can be inferred from S. $S \equiv T$ if $S^+ = T^+$

minimal cover S_c: $S_c^+ = S^+$ and not possible to remove another FD

Generate minimal cover:
1. rewrite S to have single attribute on RHS of each FD
2. For each FD $X \to A$, if $(X-B) \to B$, remove B from X
3. For each FD $X \to A$, compute X^+ without $X \to A$. If $A \subseteq X^+$, remove it

Normalisation

1st Normal Form (1NF) Every attribute depends on key. (key^+ gives all attributes)

Prime Attributes Attributes A of R that are part of a minimal candidate key X of R

3rd Normal Form (3NF) For every non trivial FD $X \to A$, either X super-key or A prime

Boyce-Codd Normal Form (BCNF) For every non trivial FD $X \to A$, X is a super key.

Lossless-join decomposition Decompose R into $R_1, \ldots, R_n$ such that $Attr(R_1) \cup \ldots \cup Attr(R_n) = Attr(R)$

FD-preserving decomposition Lossless decomposition preserve FDs if $S^+ = (S_a \cup S_b)^+$

Generating 3/BCNF: ① Find FD $(X \to A) \subseteq S$ which violates NF(X not superkey and A non-prime 3NF / X not superkey BCNF)

② Decompose R into $R_a(Attr(R) - A)$ and $R_b(XA)$ $(X \subseteq R_a \ \& \ (X \to A) \subseteq R_b)$

③ Project S onto new relations and repeat from ①

Serialisability & Recoverability

Serialisability Concurrent execution same end result as some serial execution of those transaction

Recoverability No transaction commits depending on uncomitted data

① **Lost Update** — not serialisable, recoverable — $r_1[o] < w_2[o] < w_1[o]$ removing update leads to no change

② **Inconsistent Analysis** — not serialisable, recoverable — $r_1[o_a] < w_2[o_a], w_2[o_b] < r_1[o_b]$ reading halfway through update

③ **Dirty Read** — serialisable, not recoverable — $w_1[o] < r_2[o] < e_1$

④ **Dirty Write** — not serialisable, recoverable — $w_1[o] < w_2[o] < e_1$

Serialisability conflicts occur when $(r_x[o]$ and $w_y[o])$ or $(w_x[o]$ and $w_y[o])$ are in H

H is conflict serialisable (CSR) if the serialisation graph of H is acyclic. e.g. lost update / inconsistent analysis ① ⇄ ② cycle

Recoverable (RC) if no transactions commit before another transaction it read from commits

Avoids Cascading Aborts (ACA) if no reads from non-committed transaction (no dirty read) $ST \subset ACA \subset RC$

Strict (ST) if no read from non-committed transaction (no dirty read) + no write after non-committed transaction (no dirty write.)

Concurrency

Two-Phase Locking (2PL)

① growing phase + shrinking phase → only one peak / cannot unlock then lock

② refuse $rl_i[o]$ if $wl_j[o]$ is held

③ refuse $wl_i[o]$ if $rl_j[o]$ or $wl_j[o]$ is held

} delay transaction, put on **waits-for-graph (WFG)**

If WFG has no cycle → no deadlock

If WFG has cycle → deadlock → rollback (abort) one of the transactions