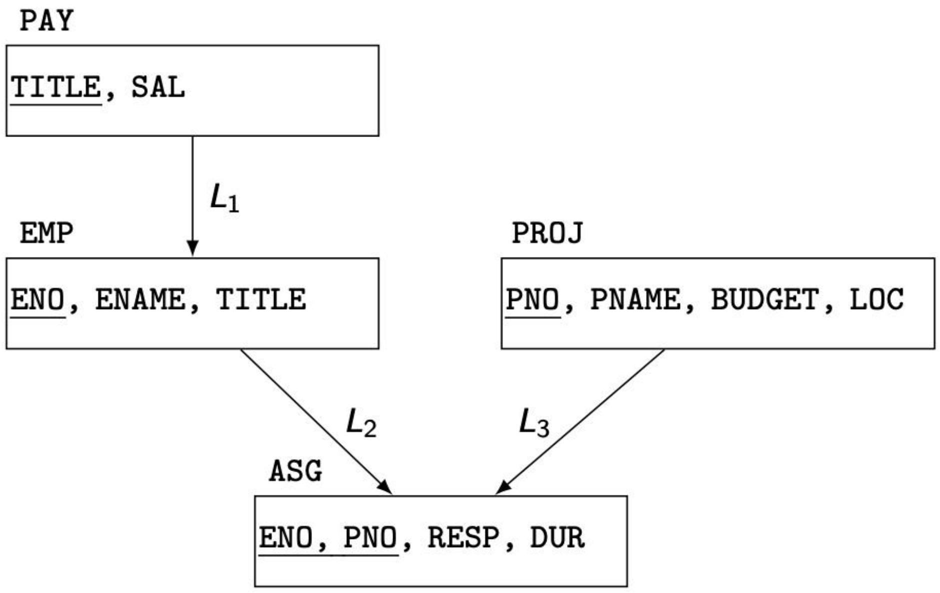
Fragmentation

- Horizontal Fragmentation (HF)
  - Primary Horizontal Fragmentation (PHF)
  - Derived Horizontal Fragmentation (DHF)
- Vertical Fragmentation (VF)
- Hybrid Fragmentation (HF)

PHF – Information Requirements

- Database Information
  - relationship



  - cardinality of each relation: *card*(*R*)

PHF – Information Requirements

- Application Information
  - **minterm selectivities**: $sel(m_i)$
    - The number of tuples of the relation that would be accessed by a user query which is specified according to a given minterm predicate m_i.
  - **access frequencies**: $acc(q_i)$
    - The frequency with which a user application *qi* accesses data.
    - Access frequency for a minterm predicate can also be defined.

Primary Horizontal Fragmentation

Definition :

$$R_j = \sigma_{F_j}(R), \quad 1 \le j \le w$$

where F_j is a selection formula, which is (preferably) a minterm predicate.

Therefore,

A horizontal fragment R_i of relation R consists of all the tuples of R which satisfy a minterm predicate m_i.

$\Downarrow$

Given a set of minterm predicates M, there are as many horizontal fragments of relation R as there are minterm predicates.

Set of horizontal fragments also referred to as minterm fragments.

PHF – Algorithm

Given: A relation *R,* the set of simple predicates *Pr*

Output: The set of fragments of $R = \{R_1, R_2, \ldots, R_w\}$ which obey the fragmentation rules.

Preliminaries :

- *Pr* should be *complete*
- *Pr* should be *minimal*

Completeness of Simple Predicates

- A set of simple predicates *Pr* is said to be *complete* if and only if the accesses to the tuples of the minterm fragments defined on *Pr* requires that two tuples of the same minterm fragment have the same probability of being accessed by any application.
- Example :
  - Assume PROJ[PNO,PNAME,BUDGET,LOC] has two applications defined on it.
  - Find the budgets of projects at each location. (1)
  - Find projects with budgets less than $200000. (2)

PHF – Example

- Fragmentation of relation PROJ
  - Applications:
    - Find the name and budget of projects given their no.
      - Issued at three sites
    - Access project information according to budget
      - one site accesses ≤200000 other accesses >200000
  - Simple predicates
  - For application (1)

    p_1 : LOC = “Montreal”

    p_2 : LOC = “New York”

    p_3 : LOC = “Paris”
  - For application (2)

    p_4 : BUDGET ≤ 200000

    p_5 : BUDGET > 200000
  - $Pr = Pr' = \{p_1,p_2,p_3,p_4,p_5\}$

PHF – Example

- Fragmentation of relation PROJ continued
  - Minterm fragments left after elimination

    m_1 : (LOC = “Montreal”) $\wedge$ (BUDGET $\leq$ 200000)

    m_2 : (LOC = “Montreal”) $\wedge$ (BUDGET > 200000)

    m_3 : (LOC = “New York”) $\wedge$ (BUDGET $\leq$ 200000)

    m_4 : (LOC = “New York”) $\wedge$ (BUDGET > 200000)

    m_5 : (LOC = “Paris”) $\wedge$ (BUDGET $\leq$ 200000)

    m_6 : (LOC = “Paris”) $\wedge$ (BUDGET > 200000)

PHF – Example

$PROJ_1$

PNO	PNAME	BUDGET	LOC
P1	Instrumentation	150000	Montreal

$PROJ_3$

PNO	PNAME	BUDGET	LOC
P2	Database Develop.	135000	New York

$PROJ_4$

PNO	PNAME	BUDGET	LOC
P3	CAD/CAM	255000	New York

$PROJ_6$

PNO	PNAME	BUDGET	LOC
P4	Maintenance	310000	Paris

PHF – Correctness

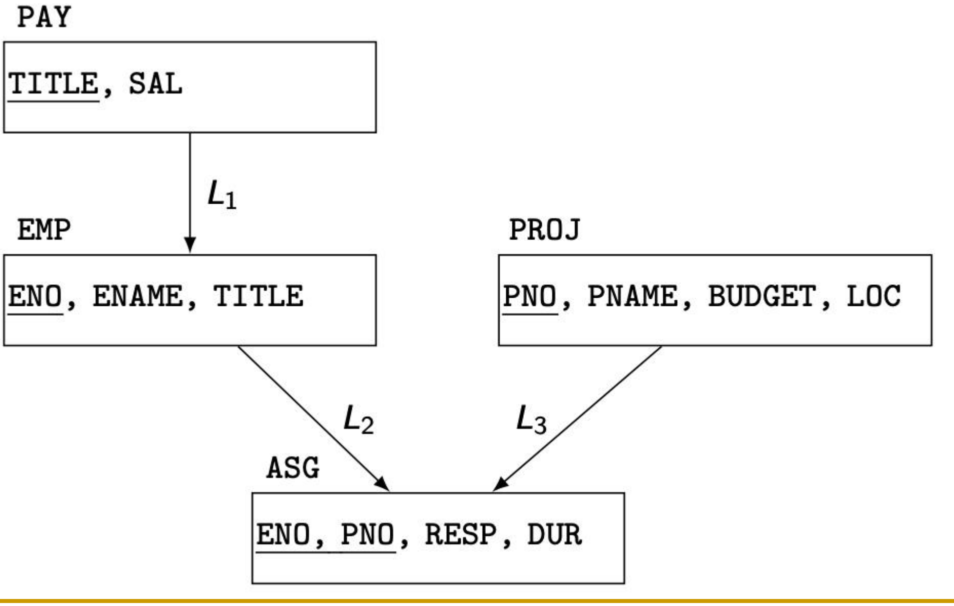
- Completeness
  - Since *Pr*' is complete and minimal, the selection predicates are complete
- Reconstruction
  - If relation R is fragmented into $F_R = \{R_1, R_2, \ldots, R_r\}$

$$R = \cup_{\forall R_i \in F_R} R_i$$

- Disjointness
  - Minterm predicates that form the basis of fragmentation should be mutually exclusive.

Derived Horizontal Fragmentation

- Defined on a member relation of a link according to a selection operation specified on its owner.
  - Each link is an equijoin.
  - Equijoin can be implemented by means of semijoins.



DHF – Definition

Given a link L where *owner*(L)=S and *member*(L)=R, the derived horizontal fragments of R are defined as

$$R_i = R \ltimes_F S_i,\ 1 \le i \le w$$

where w is the maximum number of fragments that will be defined on R and

$$S_i = \sigma_{F_i}(S)$$

where F_i is the formula according to which the primary horizontal fragment S_i is defined.

DHF – Example

Given link L_1 where owner(L_1)=SKILL and member(L_1)=EMP

$EMP_1 = EMP \ltimes SKILL_1$

$EMP_2 = EMP \ltimes SKILL_2$

where

$SKILL_1 = \sigma_{SAL \leq 30000}(SKILL)$

$SKILL_2 = \sigma_{SAL > 30000}(SKILL)$

ASG_1

ENO	PNO	RESP	DUR
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E7	P3	Engineer	36

ASG_2

ENO	PNO	RESP	DUR
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E5	P2	Manager	24
E6	P4	Manager	48
E8	P3	Manager	40

DHF – Correctness

- Completeness
  - Referential integrity
  - Let R be the member relation of a link whose owner is relation S which is fragmented as $F_S = \{S_1, S_2, ..., S_n\}$. Furthermore, let A be the join attribute between R and S. Then, for each tuple t of R, there should be a tuple t' of S such that

$$t[A] = t'[A]$$

- Reconstruction
  - Same as primary horizontal fragmentation.
- Disjointness
  - Simple join graphs between the owner and the member fragments.

Vertical Fragmentation

- Has been studied within the centralized context
  - design methodology
  - physical clustering
- More difficult than horizontal, because more alternatives exist.

  Two approaches :
  - grouping
    - attributes to fragments
  - splitting
    - relation to fragments

Vertical Fragmentation

- Overlapping fragments
  - grouping
- Non-overlapping fragments
  - splitting

We do not consider the replicated key attributes to be overlapping.

Advantage:

Easier to enforce functional dependencies

(for integrity checking etc.)

VF – Information Requirements

- Application Information
  - Attribute affinities
    - a measure that indicates how closely related the attributes are
    - This is obtained from more primitive usage data
  - Attribute usage values
    - Given a set of queries $Q = \{q_1, q_2, \ldots, q_q\}$ that will run on the relation $R[A_1, A_2, \ldots, A_n]$,

$$use(q_i, A_j) = \begin{cases} 1 \text{ if attribute } A_j \text{ is referenced by query } q_i \\ 0 \text{ otherwise} \end{cases}$$

$use(q_i, \bullet)$ can be defined accordingly

VF – Definition of $use(q_i,A_j)$

Consider the following 4 queries for relation PROJ

q_1: **SELECT** BUDGET
FROM PROJ
WHERE PNO=Value

q_2: **SELECT** PNAME,BUDGET
FROM PROJ

q_3: **SELECT** PNAME
FROM PROJ
WHERE LOC=Value

q_4: **SELECT** **SUM**(BUDGET)
FROM PROJ
WHERE LOC=Value

$$
\begin{array}{c c}
 & \begin{array}{cccc} \text{PNO} & \text{PNAME} & \text{BUDGET} & \text{LOC} \end{array} \\
\begin{array}{c} q_1 \\ q_2 \\ q_3 \\ q_4 \end{array} & \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}
\end{array}
$$

VF – Algorithm

Two problems :

- Cluster forming in the middle of the Clustered Affinity Matrix.
  - Shift a row up and a column left and apply the algorithm to find the “best” partitioning point
  - Do this for all possible shifts
  - Cost $O(m^2)$
- More than two clusters
  - m-way partitioning
  - try 1, 2, …, m–1 split points along diagonal and try to find the best point for each of these
  - Cost $O(2^m)$

VF – Correctness

A relation R, defined over attribute set A and key K, generates the vertical partitioning $F_R = \{R_1, R_2, \ldots, R_r\}$.

- Completeness
  - The following should be true for A:

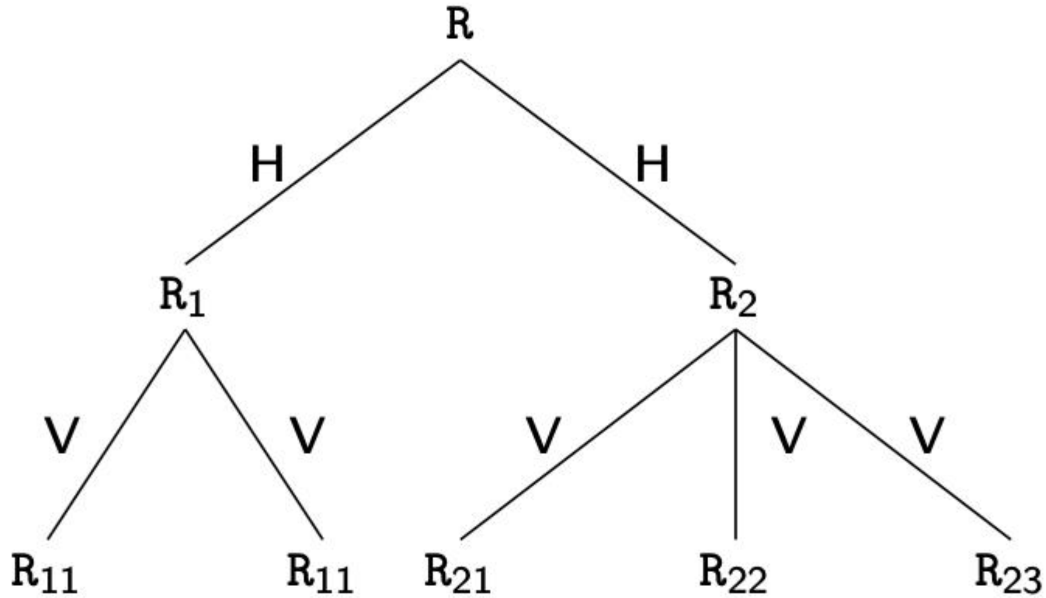
$$A = \cup A_{R_i}$$

- Reconstruction
  - Reconstruction can be achieved by

$$R = \bowtie_K R_i, \; \forall R_i \in F_R$$

- Disjointness
  - Tuple Identifiers (TID's) are not considered to be overlapping since they are maintained by the system
  - Duplicated keys are not considered to be overlapping

Hybrid Fragmentation



Reconstruction of Hybrid Fragmentation