# Superviews: Virtual Integration of Multiple Databases

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# The Problem

- ✓ A database should provide each application with a single integrated view of all the data it requires.
  - One of the original motivations behind the invention of databases.
- ✓ Eventually, applications evolve that are no longer satisfiable from a single database.
  - The existence of multiple, relevant databases negates the above advantage.
  - Many database management systems do not allow accessing more than one database at a time.

# Possible Solutions

- ✓ Consolidate the multiple databases in a single database.
  - Costly; justified only when the new requirements are permanent.
  - It may be desirable to keep the independence of individual databases.
  - It is impossible, if the databases are provided by external sources.
- ✓ Develop a multidatabase language.
  - Access and combine data from individual databases.
  - Example: MALPHA [Litwin 84]
- ✓ Construct a virtual database.

# Virtual Database

- ✓ Actual database: <*schema*, *data*>
- ✓ Virtual database: <*schema*, *mapping*>
  - Schema describes the entire multidatabase environment (*virtual* schema).
  - No data.
  - Instead, the mapping links the schema to the schemas of other databases.
  - The target databases could be virtual, as well.
  - The mapping can be interpreted as another form of data.
- ✓ Integration need not be "total."
- ✓ With respect to permanency: virtual database schemas are somewhere between the fixed schemas of physical databases, and the transient views formed by MALPHA queries.

# Superviews: Main Components

- ✓ Virtual Database Generator
  - An interactive program that creates a virtual database (schema and mapping) from individual database schemas.
  - The user “stitches” the individual schemas with integration statements.
  - The process also yields a mapping from the new schema to the individual schemas.
- ✓ Virtual Query Processor
  - Software that processes *global* queries (queries on the virtual database).
  - It employs the mapping to *decompose* each global query to a set of queries against the individual databases.
  - It recomposes the set of answers received in an answer to the original query.
  - The process is *transparent* to the user (as if an actual database existed).

# Related Research

- ✓ Multidatabase systems
  - Multibase
  - ADDS
- ✓ Physical consolidation
  - Restructuring
  - Data translation
- ✓ Design methodology
  - View integration

# The Data Model: A Functional Approach

- ✓ The functional approach to data modeling was first described in [Sibley and Kerschberg 1977].
- ✓ Various flavors; we define our own version.
- ✓ Basic notions:
  - *Domain*: set of values.
  - *Function*: Assigns values of one domain to another domain.
  - Two types of functions: *attribute*, *generalization.*

# The Functional Model: Basic Concepts

A database is

1. A collection $D$ of named *classes*.
2. Two relations **att** and **gen** defined on $D$.
   - Their intersection is empty.
   - Their union has irreflexive transitive closure.
3. Each class $S \in D$ has
   - A *domain* **dom**($S$) of values.
   - A *type*: **type**($S$) = {T | T **att** S}.
   - A *key*: $K \subseteq$ **type**($S$), denoted $K$ **key** $S$.
4. Extensions
   - Every relationship $T$ **att** $S$ is supported by a function:
     $f_{st}$ : **dom**($S$) → **dom** ($T$)
   - Every relationship $T$ **gen** $S$ is supported by an *injective* function:
     $i_{st}$ : **dom**($S$) → **dom**($T$)

# Basic Concepts (*cont.*)

5. Compositions
   1. Inheritance of attributes over generalizations:
      $S$ **att** $T$, $T$ **gen** $R \Rightarrow S$ **att** $R$, $f_{RS} = i_{\mathrm{RT}} \circ f_{TS}$
   2. Transitivity of generalizations:
      $S$ **gen** $T$, $T$ **gen** $R \Rightarrow S$ **gen** $R$, $i_{RS} = i_{RT} \circ i_{TS}$
6. Keys
   1. If $(T_1, \dots, T_K)$ **key** $S$ and
      $f_{STi} : S \rightarrow T_i$ (i=1, … , $k$) are the **att** functions,
      then
      $$f : \mathbf{dom}\,(S) \rightarrow \mathbf{dom}(T_1) \times \cdots \times \mathbf{dom}(T_k)$$
      $$f(s) = (f_{ST1}(s), \dots, f_{STk}(s))$$
      is an injection.
   2. $K$ **key** $S$, $S$ **gen** $T \Rightarrow K$ **key** $T$

# Example

- Classes:

  FACULTY, STUDENT, PERSON, PIN, NAME, RANK, GPA

- Class relationships:

| | |
|---|---|
| PIN **att** FACULTY | NAME **att** STUDENT |
| PIN **att** STUDENT | NAME **att** PERSON |
| PIN **att** PERSON | GPA **att** STUDENT |
| RANK **att** FACULTY | PERSON **gen** FACULTY |
| NAME **att** FACULTY | PERSON **gen** STUDENT |

- Types:

  **type**(FACULTY) = (PIN, NAME, RANK)

  **type**(STUDENT) = (PIN, NAME, GPA)

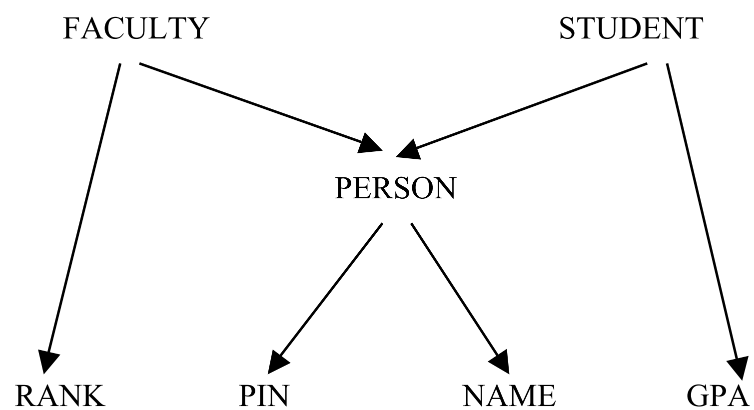
  **type**(PERSON) = (PIN, NAME)

- Keys:

  PIN **key** PERSON

  PIN **key** STUDENT

  PIN **key** FACULTY



# Query Language vs. Access Operators

- ✓ Functional query language, similar to DAPLEX [Shipman 1981].
  - Example

    **for each** ENROLLMENT

    **such that** COURSE(ENROLLMENT) = 'CS101'

    **and** GRADE(ENROLLMENT) = 'A'

    **print** NAME(STUDENT(ENROLLMENT))
- ✓ This language is implemented with a minimal set of *access operators*:
  - *Domain*: Retrieve the values in the domain of $S$.

    $\{S\} \equiv \mathbf{dom}(S)$
  - *Function:* Retrieve the value assigned to $s \in S$ by attribute $T$.

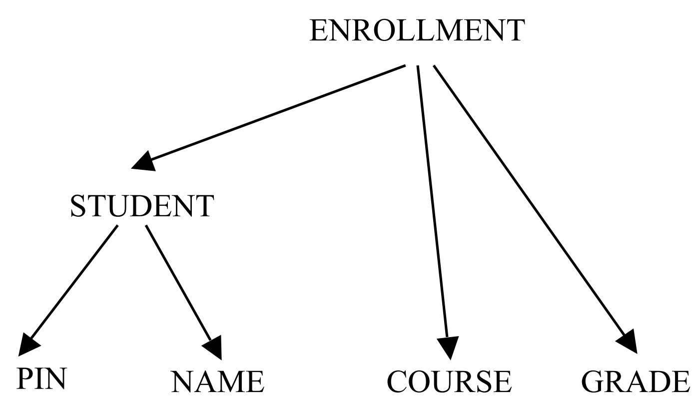
    $T(S{=}s) \equiv f_{ST}(s)$
  - *Inverse:* Retrieve the set of values in **dom***(S)* that have the value $t$ for attribute $T$.

    $\{S(T{=}t)\} \equiv f^{-1}_{ST}(t)$

# Example

- ✓ The previous query is translated by using these access operators in a host language:

**for each** $x$ **in** {ENROLLMENT} **do**
**begin**
  **if** COURSE(ENROLLMENT = $x$) = ‘CS101’
  **and** GRADE(ENROLLMENT = $x$) = ‘A’
  **then do**
  **begin**
    $y$ := STUDENT(ENROLLMENT = $x$);
    **print** NAME(STUDENT = $y$)
  **end**
**end**.



# The Integration Language

The language consists of 10 operators (2 of which may be emulated by sequences of other operators).

✓ Manipulate the generalization hierarchy
  - Meet
  - Join
  - Fold
  - Combine and Connect (sequences of meet and fold)

✓ Modify the attribute hierarchy, to iron-out structural differences between two schemas:
  - Aggregate
  - Telescope
  - Add
  - Delete

✓ Other
  - Rename

# Constructing A Superview

- ✓ Illustrate the technique with example

# Deriving the Mapping

- ✓ Associate with each final class an expression that denotes the *origins* of this class, in terms of classes of the initial databases.
- ✓ Obtained incrementally during the integration process.
- ✓ Each operation updates the expressions of the classes it creates or modifies.
- ✓ The expressions associated with the final classes constitute the *mapping*.
- ✓ Example:
  - Classes SUPPLIER and CUSTOMER are generalized to ASSOCIATE,
  - Then TEL-NO is deleted from ASSOCIATE.
  - The expression associated with the final class ASSOCIATE is:

    $((\text{SUPPLIER} \wedge \text{ASSOCIATE})_1 - \text{TEL-NO})_2$

# Query Translation

When an access operator is submitted to a superview

- ✓ It is translated over each of the integration operators that were involved in the classes that it addresses.
- ✓ The order of translation is the reverse order of the application.
- ✓ The final answers (the answers to queries submitted to the actual databases) are passed back in reverse direction.
- ✓ These answers are recomposed, until an answer to the original query is obtained.
- ✓ We need rules for translating each of 3 access operators over 10 possible integration operators — total 30 rules.
- ✓ We need rules for combining answers obtained from different databases.

# Query Translation (*Cont.*)

Example (3 of the 30 rules):

- ✓ Consider the operator **meet** *S* **and** *T* **into** *Q*.
- ✓ Assume *R* is attribute of *Q*.
- ✓ Three access operators need translation:
  - The *domain* of *Q*:

    $\{Q\} \equiv \{S\} \cup \{T\}$
  - A *function* operator from *Q* to *R*:

    $R(Q = x) \equiv R(S = x) \vee R(T = x)$

    $\vee$ is the *best-valu*e operator: combines two values as in the "best" way.
  - An *inverse* operator from *R* to *Q*:

    $\{Q(R = y)\} \equiv \{S(R = y)\} \oplus \{T(R = y)\}$

    $\oplus$ is the *best-set* operator: combines two sets in the "best" way.

# The Best-Value Operator

Combines two *function* operators.

- ✓ $T(S = s) =$
  - [*not applicable*] if $T \notin \mathbf{type}(S)$
  - [*not-found*] if $s \notin \mathbf{dom}(S)$
  - [not-available] if $f_{ST}(s)$ is undefined
  - $f_{ST}(s)$ otherwise
- ✓ Each successive situation is more "successful".
- ✓ The *best-value* operator combines two values with the more successful of the two.
- ✓ However, two different values (both are of the fourth type) are combined with [*not-consistent*].

# The Best-Set Operator

Combines two *function* operators.

- ✓ $\{S(T = t)\} =$
  - [*not applicable*] if $T \notin \mathbf{type}(S)$
  - [*not-found*] if $s \notin \mathbf{dom}(T)$
  - $f^{-1}_{ST}(t)$ otherwise
- ✓ Each successive situation is more "successful".
- ✓ The *best-set* operator combines two values with the more successful of the two.
- ✓ However, two different sets (both are of the third type) are combined with their *union*.

# Conclusion

- ✓ Defined a new approach to database integration.
- ✓ Some issues:
  - Update of virtual databases
  - Data incompatibility
  - Merging heterogeneous databases (not in the functional model)