Database Foundations

data design separated from process design

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the effect of process structure omitted for data design

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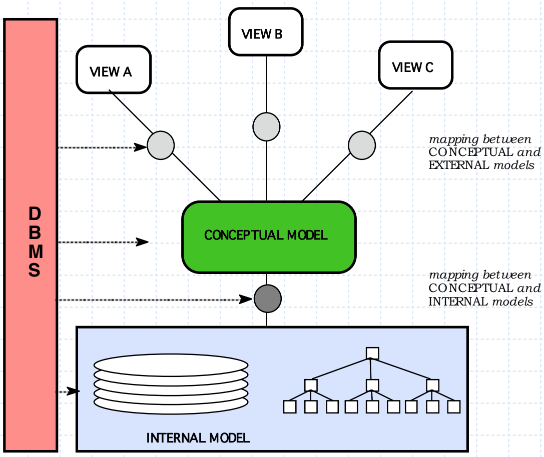
relationships between data and processes are of the ***first-order*** type

thus the final '***technical***' design is achieved by linear superposition



benefits

- Data redundancy minimized
- Data shared amongst applications
- Data maintained centrally
- Common processes between applications
- Application software transparent

Relational Model

$\mathbf{R} = (r_1, r_2, \ldots r_{i-1}, r_i, r_{i+1}, \ldots r_n)$ — relation as a constrained subset of a product of simple domains

- none of $r_i = (r_{i1}, r_{i2}, \ldots)$ — 1NF
- $\{R_i\}$ is closed under $\Pi, \sigma, \eta, \ldots$ — relational closure
- $\exists\, k = (r_i, r_j, \ldots)$: $[\Pi \mathbf{R}(k)] \equiv [\mathbf{R}]$ — identifier (PK)

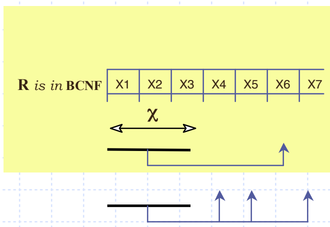
FD: $X \rightarrow Y$ holds for $\mathbf{R} = (\ldots, X, Y, \ldots)$ iff $\forall\, x \in X$, $[\Pi\sigma\, \mathbf{R}(X{=}x)Y] \leq 1$ — functional dependency

Relational Optimisation

$\{R_i\} \rightarrow \{S_k\}$

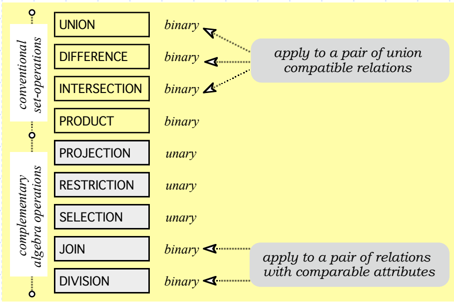
- No transaction may
  - cause loss of information — delete anomaly
  - violate entity integrity — insert anomaly
  - carry any risk of inconsistent updating — update anomaly
- Minimized data redundancy

Boyce-Codd Normal Form

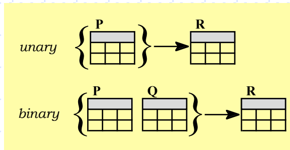


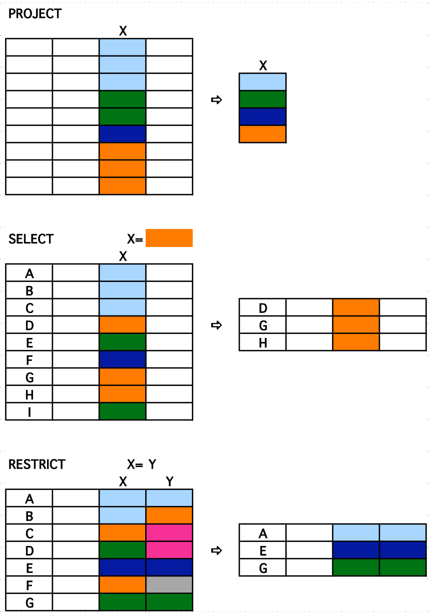
A 1NF relation $\mathbf{R}(\mathbf{X_1}, \mathbf{X_2}, \ldots \mathbf{X_n})$ is in **BCNF** iff:
for every attribute collection χ of **R**
if any attribute not in χ is functionally dependent on χ
then all attributes in **R** are functionally dependent on χ

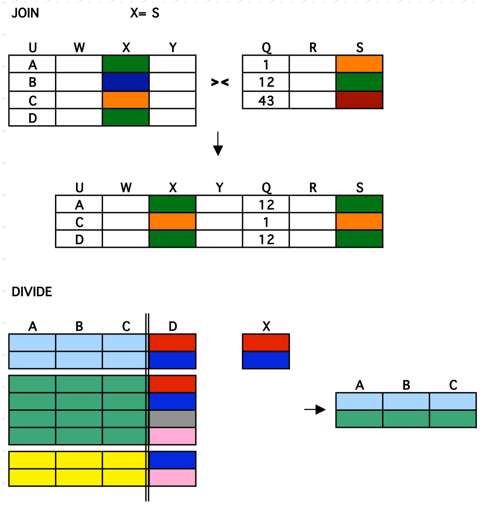
Relational Algebra



Relational Closure








```
[example] :-) print subject
class class_name
----- ---------------
C1    FICTION
C2    SCIENCE-FICTION
C3    NON-FICTION
C4    SCIENTIFIC
C5    POETRY
C6    DRAMA
Message: Relation subject re
```

http://leap.sourceforge.net/

```
[example] :-) print index
author     title                              class shelf
---------- ------------------------------ ----- -----
JOYCE      ULYSSES                            C1    12
GREENE     SHORT STORIES                      C1    14
ORWELL     ANIMAL FARM                        C1    12
LEM        ROBOTS TALES                       C2    23
LEM        RETURN FROM THE STARS              C2    23
GOLDING    LORD OF THE FLIES                  C1    12
KING       STRENGTH TO LOVE                   C3    24
HEMINGWAY  DEATH IN THE AFTERNOON             C3    22
HEMINGWAY  TO HAVE AND HAVE NOT               C1    12
Message: Relation index returned.
```

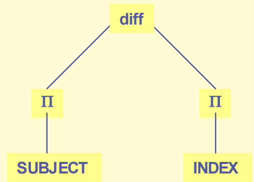
```
[example] :-) print book
reference author    title
--------- --------- --------
---
R003      JOYCE     ULYSSES
R004      JOYCE     ULYSSES
R023      GREENE    SHORT STORIES
R025      ORWELL    ANIMAL FARM
R033      LEM       ROBOTS TALES
R034      LEM       RETURN FROM THE STARS
R036      GOLDING   LORD OF THE FLIES
R028      KING      STRENGTH TO LOVE
R143      HEMINGWAY DEATH IN THE AFTERNOON
R149      HEMINGWAY TO HAVE AND HAVE NOT
Message: Relation book returned.
```

```
[example] :-) b=(project (subject) (class))
                difference
               (project (index) (class))
Message: Relation b returned.

[example] :-) print b

class
-----
C4
C5
C6
Message: Relation b returned.

[example] :-) quit
Message: Closing [s] database……
```



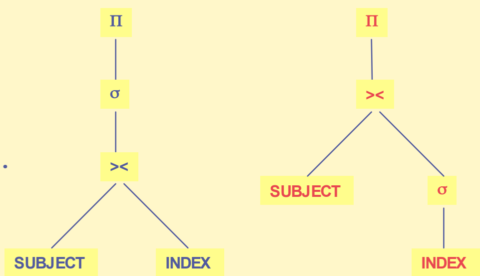

```
[example] :-) a = project (select (join (subject)(index)
                                  (subject.class = index.class))
                         (class_name = 'SCIENCE-FICTION'))
                  (title)
Message: Relation a returned.

[example] :-) print a

title
------------------------------
ROBOTS TALES
RETURN FROM STARS

Message: Relation zzgxic returned.

[example] :-) quit
Message: Closing [s] database……
```



Why relational model has been so attractive ?

- separation of physical & logical aspects
- data - process independence
- high level of data abstraction
- universal & uniform data structure
- global behavioural rules
- set of higher-level operations
- structure optimisation algorithm

How was it possible

- data - process independence
  - divorce from ADT
    - the only sensible way to do it:
      → make all operations universally applicable to every structure
      - the only sensible way to do it:
        → have one universal primitive

Conclusion

any kind of ordering (set inclusion, tree, graph, convolution) imposed on a structure contradicts relational foundations

→ evolution of RDB imminent

Objectives

- structural simplicity → structural uniformity (regularity)
- separation of logical and physical aspects of database processing
- set-oriented processing → algebra-oriented processing

M_0 = {ADT, procedures}

↓

M_1 = {relations, r-operations} E. Codd

↓

M_2 = {nested relations, xr-operations} H. Korth *at al*.

↓

M_3 = {L, *operations*} D. Scott

↓

M_4 = {algebra (components, operations), transformations}

Abrial's Binary Model

KNOWLEDGE ::=

ELEMENTARY FACTS

- John Doe was born in London on 19 Nov 1962
- The car with a number plate B1 BYE is a Ferrari

SIMPLE RULES

- Every man has necessarily two parents of whom he is the child
- A person has sometimes a spouse and if X is the spouse of Y then Y is the spouse of X
- A car has (if any) only one owner. Conversely, an owner may have zero, one or several cars

COMPLEX RULES

- The sex of a person is not subject to any change
- A single person who marries may not be single again in the future
- A person may not be, at a given time, in two different places

DEDUCTIVE RULES

- if x > y then BIG:= x else BIG:= y
- square() = twice (twice ())

WHEN THE MODEL DOES NOT KNOW A FACT OR A LAW ABOUT REALITY
THIS DOES NOT MEAN THAT THIS FACT OR LAW DOES NOT EXISTS,

CONSEQUENCE:

IF

THE MODEL HAS EXACTLY THE SAME KNOWLEDGE OF TWO OBJECTS
IT DOES NOT FOLLOW THEY ARE ONE AND THE SAME OBJECT.

THEREFORE

AN OBJECT ENTERING THE 'PERCEPTION FIELD' OF THE MODEL MUST
IDENTIFY ITSELF AS either NEW OBJECT or ALREADY KNOWN OBJECT

THE DESCRIPTION OF AN OBJECT INSIDE THE MODEL IS GIVEN VIA THE
CONNECTIONS (access functions) IT HAS WITH OTHER OBJECTS

person_of_sex (MALE) = {JOHN, PETER}

person_of_sex (FEMALE) = {JANE, MARY}

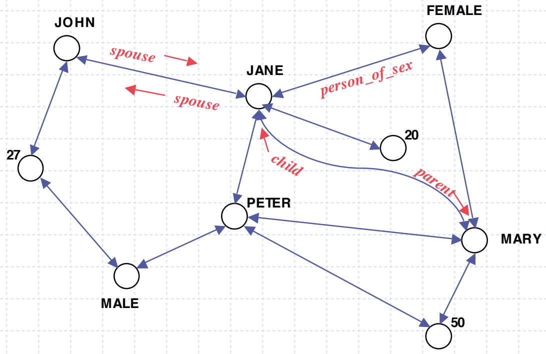
age (JOHN) = {27}

person_of_age (50) = {PETER, MARY}

child (PETER) = {JANE}

parent (JANE) = {PETER, MARY}

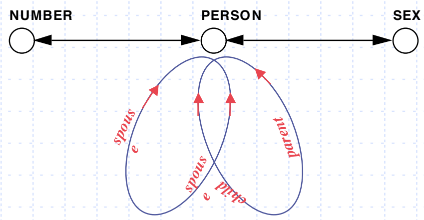
. . .



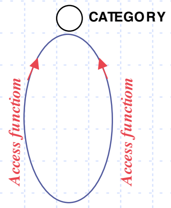
CATEGORIES

JOHN, JANE, PETER, MARY	are	PERSONs
27, 50, 20	are	NUMBERs
MALE, FEMALE	are	SEXes

THUS, THE STRUCTURE OF THE EXAMPLE CAN BE ABSTRACTED INTO



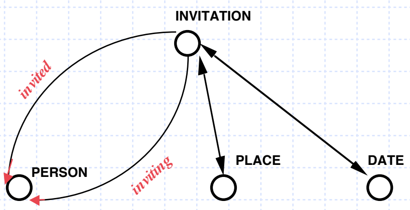
AND FURTHER STILL INTO

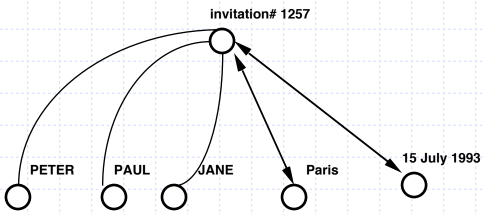


CONNECTIONS MAY THEMSELVES REQUIRE SOME INFORMATION

EXAMPLE: PETER was_invited_by (PAUL and JANE) to PARIS on 15Jul1993

THIS CAN BE DESCRIBED BY BUILDING A NEW CATEGORY- INVITATION
AND THE FOLLOWING STRUCTURE





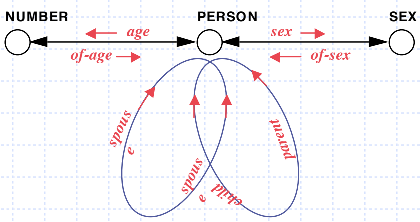
defn CATEGORIES

PERSON = cat — there is new category

JOHN = generate PERSON — create new object of category

x ← generate PERSON

kill JOHN, kill x



a person has exactly one sex, one age, two parents, zero or one spouse and any number of children

r1 = rel (PERSON, SEX, ***sex*** = fun(1, 1), ***of_sex*** = fun (0, ∞))

r2 = rel (PERSON, NUMBER, ***age*** = fun(1, 1), ***of_age*** = fun (0, ∞))

r3 = rel (PERSON, PERSON, ***spouse*** = fun(0, 1), spouse)

r4 = rel (PERSON, PERSON, ***parent*** = fun(2, 2), ***child*** = fun (0, ∞))

min ***max***