## 2IS55 Software Evolution

# Implementing evolution: Database migration

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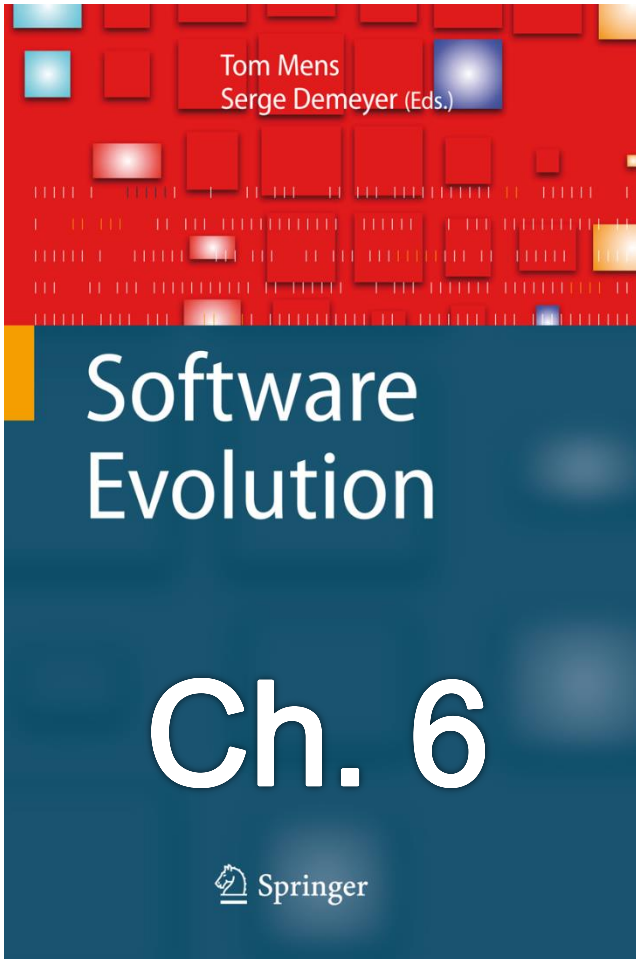
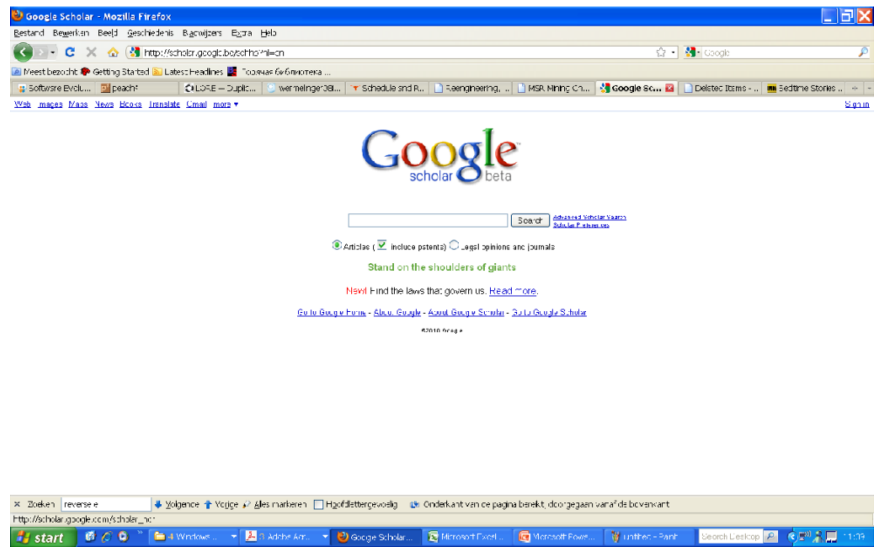
Where innovation starts

# Sources


Tom Mens
Serge Demeyer (Eds.)
Software Evolution
Ch. 6
Springer

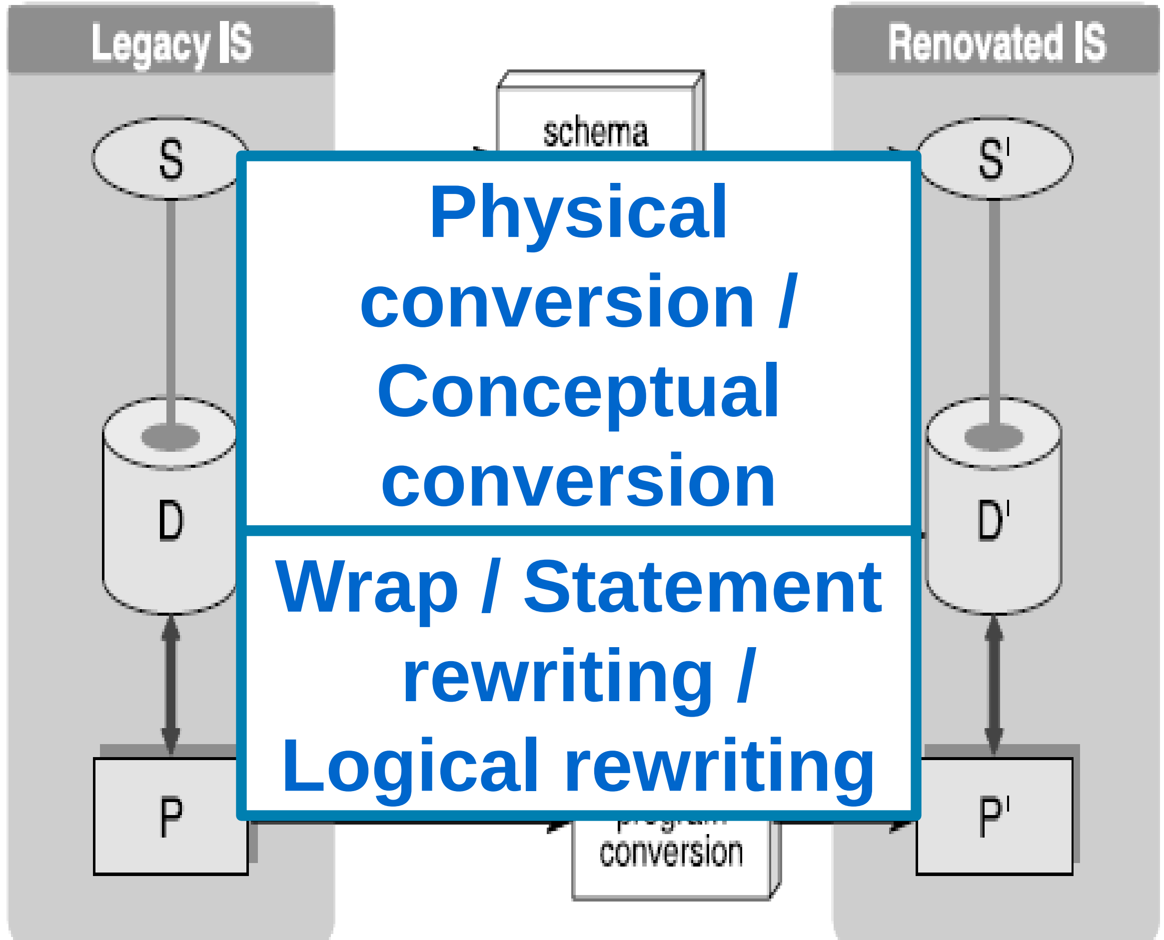

Google Scholar - Mozilla Firefox
Google scholar beta
Stand on the shoulders of giants

# Databases

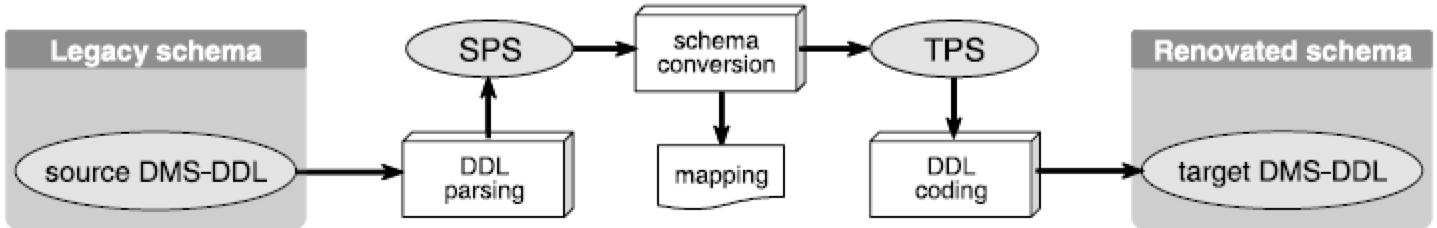
- Central for information systems
- Contain major company assets: data
- Often developed using outdated technology
  - COBOL might not be hot but is still very much alive
    - 220 bln LOC are being reported
- Migration should
  - Preserve the data
  - Improve the technology used
    - Flexibility
    - Availability of skills

# Database migration

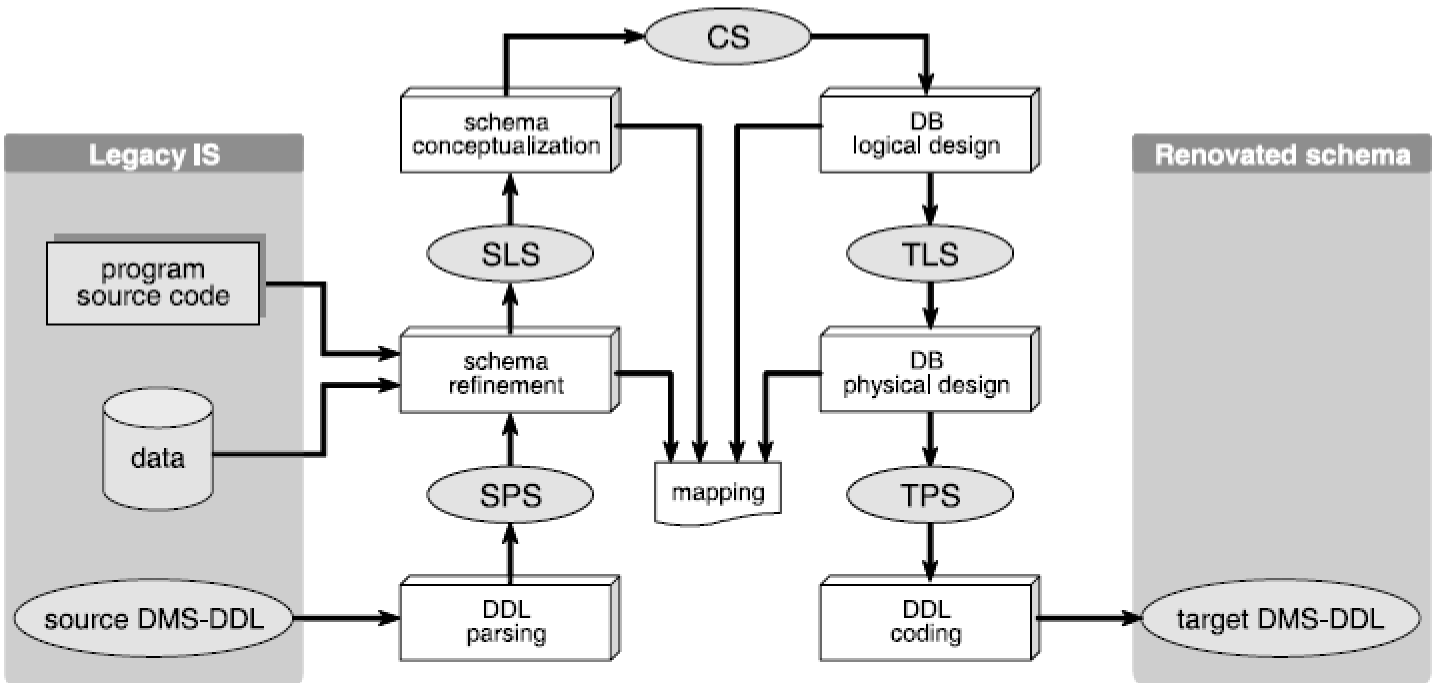
- **S – DB schema**
- **D – DB data**
- **P – data manipulation programs**



# Schema conversion: Physical vs Conceptual




***Physical***




***Conceptual***



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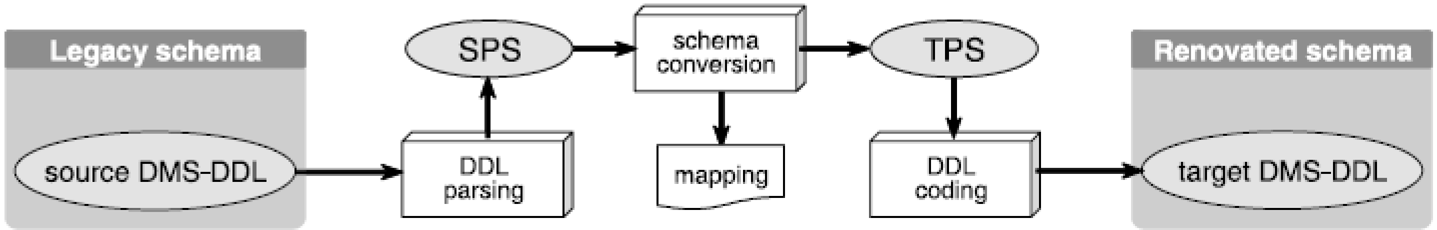
# Schema conversion: Physical




## SQL

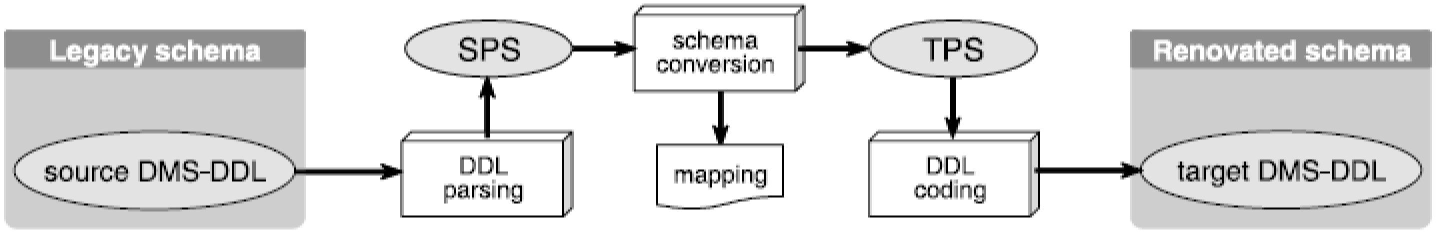
CREATE TABLE **PERSON-ITEM**
(PERSON-ID varchar(4) PRIMARY KEY,
PERSON-NAME varchar(20),
PERSON-ADDRESS varchar(20),
PERSON-CITY varchar(18))

## COBOL

DATA DIVISION.
FILE SECTION.
FD PERSON-FILE
DATA RECORD IS **PERSON-ITEM**.
01 PERSON-ITEM.
02 PERSON-KEY.
03 PERSON-ID PICTURE X(4).
02 PERSON-NAME PICTURE X(20).
02 PERSON-ADDRESS PICTURE X(20).
02 PERSON-CITY PICTURE X(18).

**Advantages and disadvantages of physical conversion?**

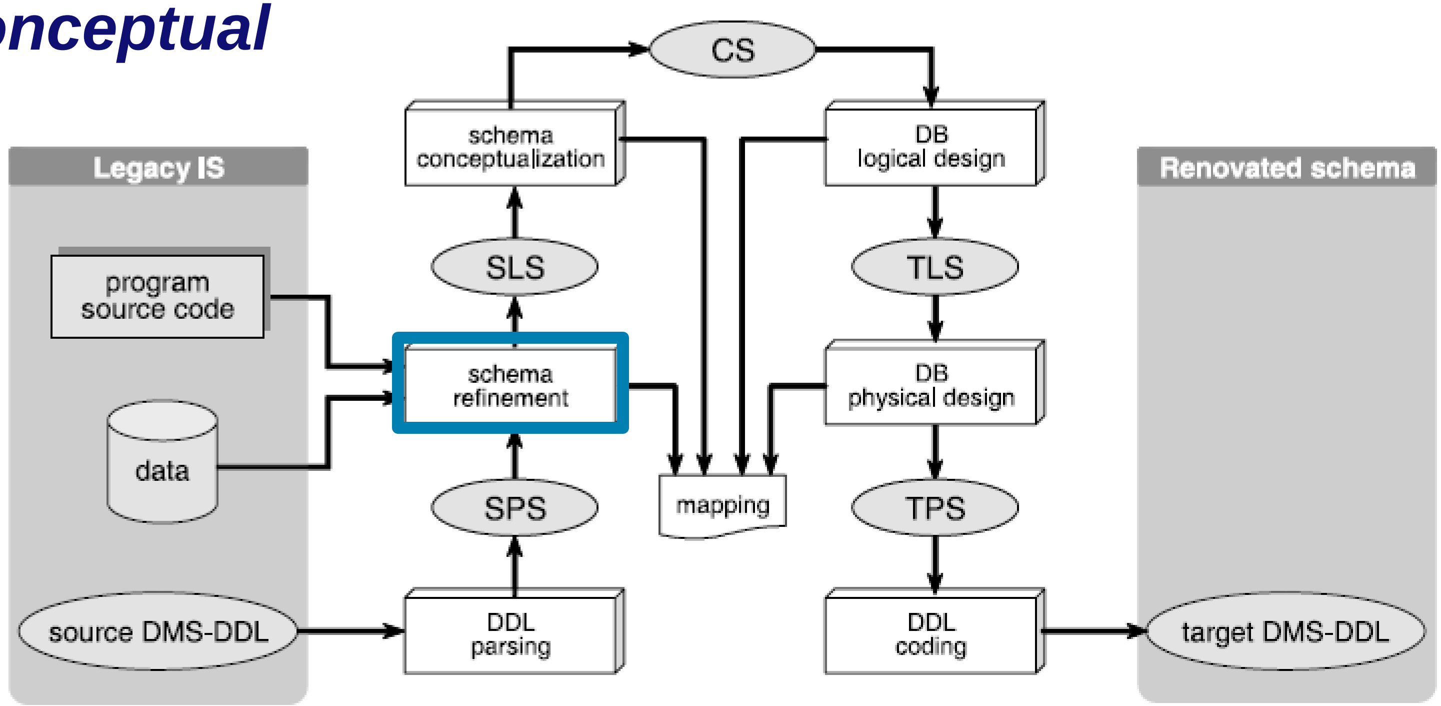
# Schema conversion: Physical




- Easy to automate
  - Existing work: COBOL ⇒ relational, hierarchical ⇒ relational, relational ⇒ OO
- "Migration as translation" vs "migration as improvement"
- Semantics is ignored
  - Limitations of COBOL ⇒ Design decisions in the legacy system ⇒ Automatic conversion ⇒ the same design decisions in the new system
    - Risk: compromised flexibility

# Schema conversion: Physical vs Conceptual

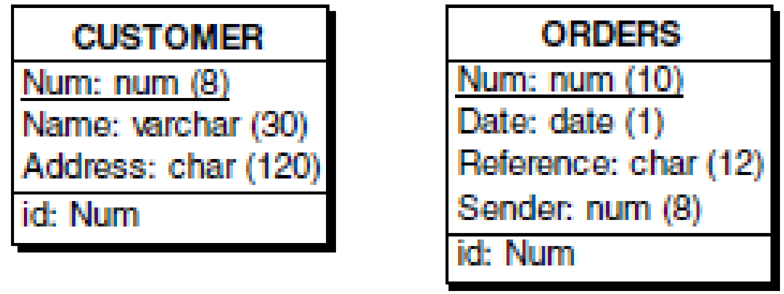
## *Conceptual*




- **Refinement: Data and code may contain implicit constraints on the schema**
- **Conceptualization: Remove implementation details**

# Implicit constraints [Cleve, Hainaut 2008]

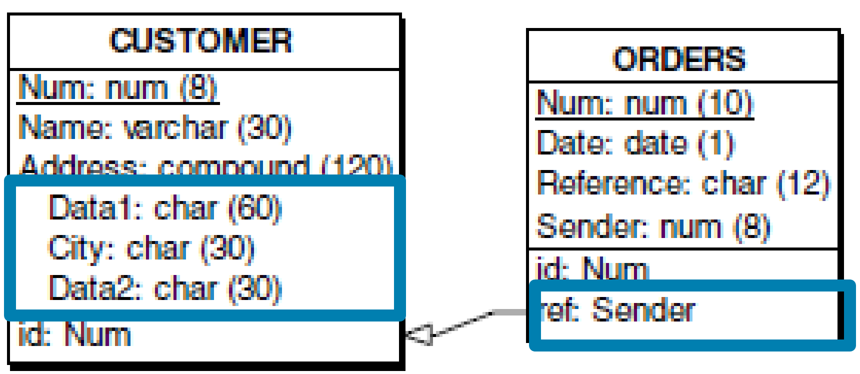
- **DB schema as defined by DDL commands**
- **Query**




```
select substring(Address from 61 for 30) into :CITY
from CUSTOMER C, ORDERS O
where C.Num = O.Sender and O.Num = :ORDID
```

- **What are the implicit constraints implied?**

**Field refinement**




**Foreign key elicitation**

# Field refinement

- **Explicit**
  - **select substring(Address from 61 for 30) into :CITY**
- **Implicit: 4 code fragments**

a) **Local variable ("working storage")**

```
01 DESCRIPTION
   02 NAME PIC X(20).
   02 ADDRESS PIC X(40).
   02 FUNCTION PIC X(10).
   02 REC-DATE PIC X(10).
```

b) **DB table ("file section")**

```
FD CUSTOMER.
01 CUS.
   02 CUS-CODE PIC X(12).
   02 CUS-DESCR PIC X(80).
   02 CUS-HIST PIC X(1000).
```

c) `MOVE DESCRIPTION TO CUS-DESCR.`

d) `MOVE CUS-DESCR TO DESCRIPTION.`

- **CUS-DESCR and DESCRIPTION refer to the same data**
- **They should have the same structure**

# How can we elicit foreign keys?

- Statically and dynamically
  - Do you remember the difference?

- Statically:
  - Parsing (easy for COBOL, difficult for Java)
  - M.Sc. thesis of Martin van der Vlist:

  “Quality Assessment of Embedded Language Modules”

- Dynamically:
  - Instrument the code
  - Capture traces
  - “Guess constraints”

# Cardinality constraints: As defined

```
01 LIST-DETAIL.
   02 DETAILS OCCURS 20 TIMES
          INDEXED BY IND-DET
        03 REF-DET-STK PIC 9(5)
        03 ORD-QTY PIC 9(5)
```

- **Local variable**
  - **Array of 20 elements**
- **DB attribute**

```
FD ORDER.
01 ORD.
   02 ORD-CODE PIC 9(10)
   02 ORD-CUSTOMER PIC X(12).
   02 ORD-DETAIL PIC X(200).
```

- **represent the same info**

```
MOVE LIST-DETAIL TO ORD-DETAIL.
```

- **Hence, ORD can be associated to not more than 20 details (and not less than 0 details – trivial)**
  - **As defined**
  - **What about the use?**

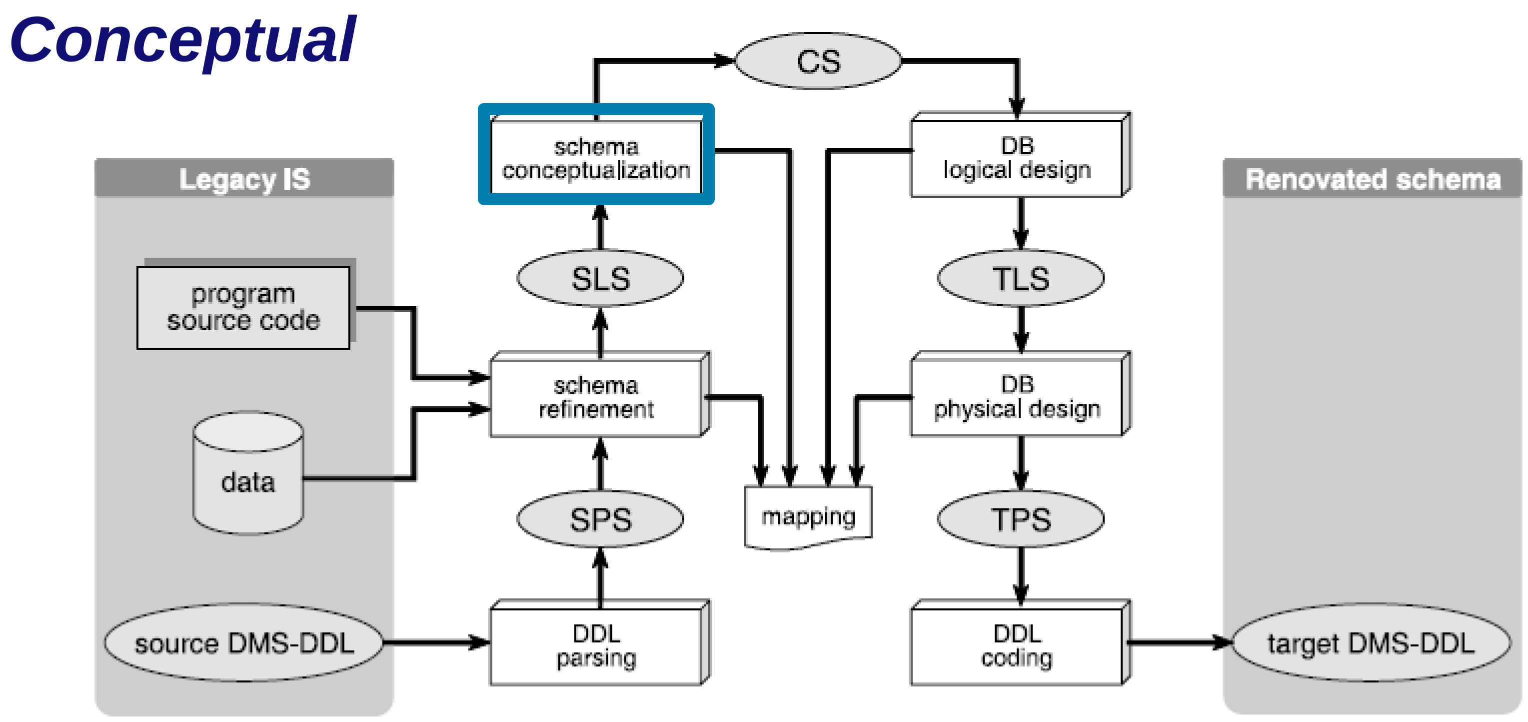
# Cardinality constraints: As used

- Look for list traversals: e.g., reading data

```
SET IND-DET TO 1.
MOVE 1 TO END-FILE.
PERFORM READ-DETAIL
   UNTIL END-FILE = 0 OR IND-DET = 21.
MOVE LIST-DETAIL TO ORD-DETAIL.
```

- Here: cardinality as used = cardinality as defined
  - Not always the case

# Schema conceptualization

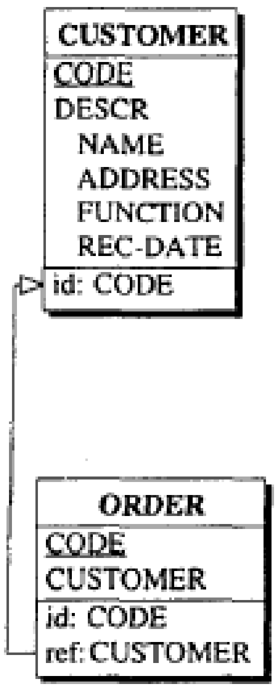



- So far we only added complexity to the schema
- Conceptualization: Remove implementation details

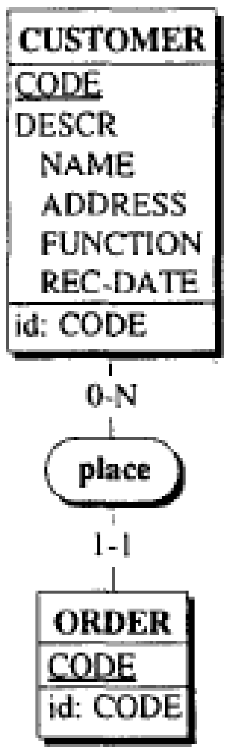
# Conceptualization

- Preparation: “clean up” to understand
  - e.g., rename attributes, drop one-element compounds
- Untranslation: separate logic from limitations of technology
- De-optimization: separate logic from performance
- Conceptual normalization:
  - Entities vs. relations and attributes
  - Explicit IS-A relations

# Untranslation: Foreign keys




- COBOL allows “direct access” via foreign keys
- ER requires a relationship set to connect two entities
- What would be the appropriate cardinality?
  - One customer can place multiple orders
  - Every order can be placed only by one customer





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# De-optimization

- **Recall:**

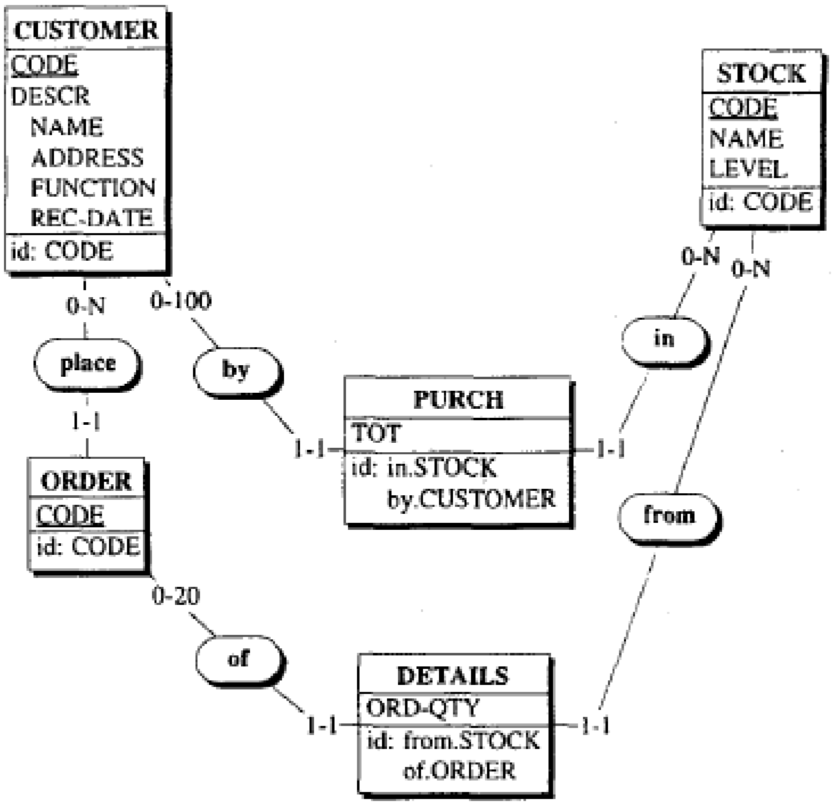
```
FD ORDER.
01 ORD.
  02 ORD-CODE PIC 9(10).
  02 ORD-CUSTOMER PIC X(12).
  02 ORD-DETAIL PIC X(200).
```

```
01 LIST-DETAIL.
  02 DETAILS OCCURS 20 TIMES
       INDEXED BY IND-DET.
    03 REF-DET-STK PIC 9(5).
    03 ORD-QTY PIC 9(5).
```

- **ORD-DETAIL is a complex multi-valued attribute**
  - **Highly efficient COBOL trick**
- **ORD-DETAIL cannot exist without an order**

- **How would you model this in ER?**
  - **Weak entity set**
  - **One-to-many relationship**

# Conceptual normalization




- **What would you like to improve in this schema?**
  - **Are the cardinality constraints meaningful?**
  - **Which entities are, in fact, relations?**
  - **Are there unneeded structures?**



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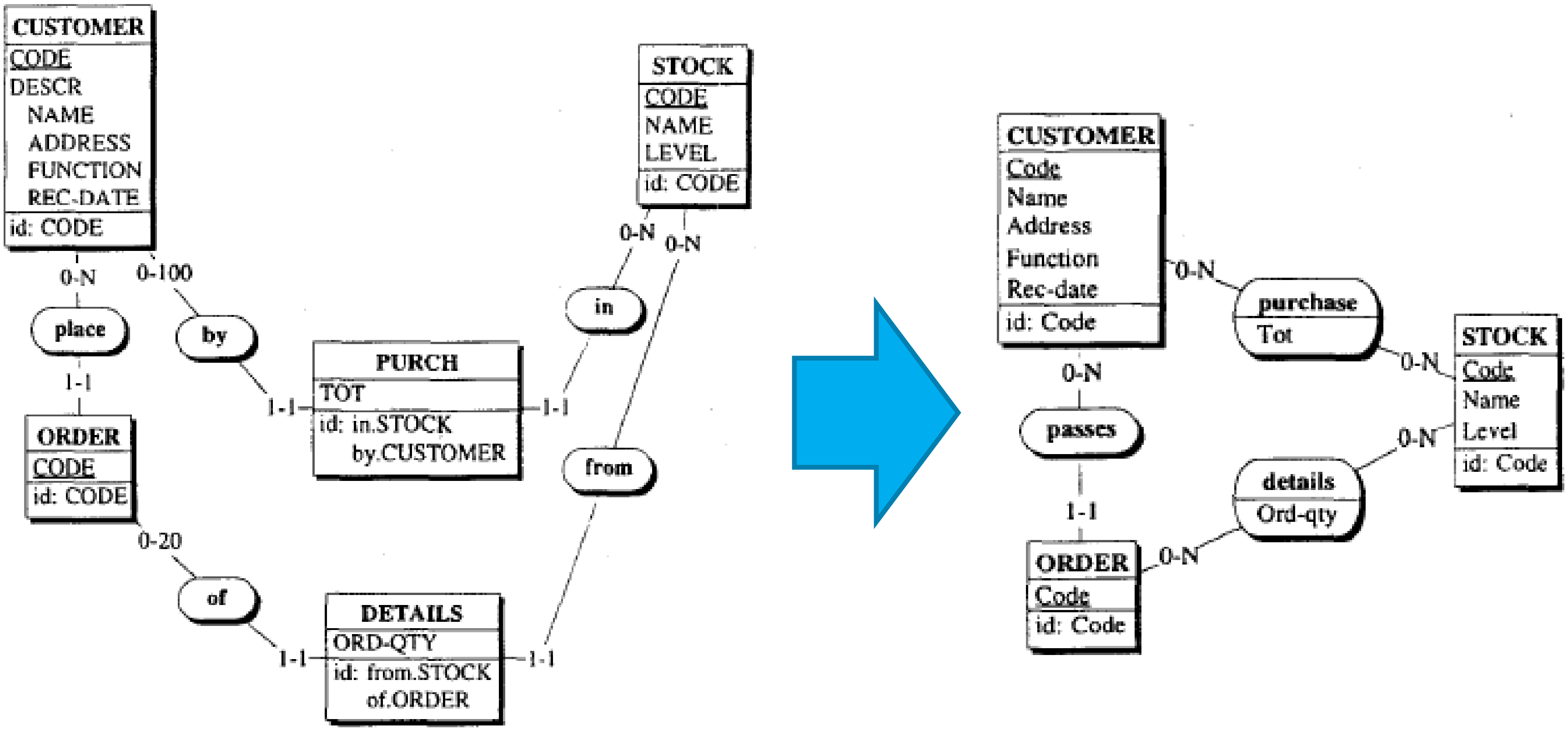
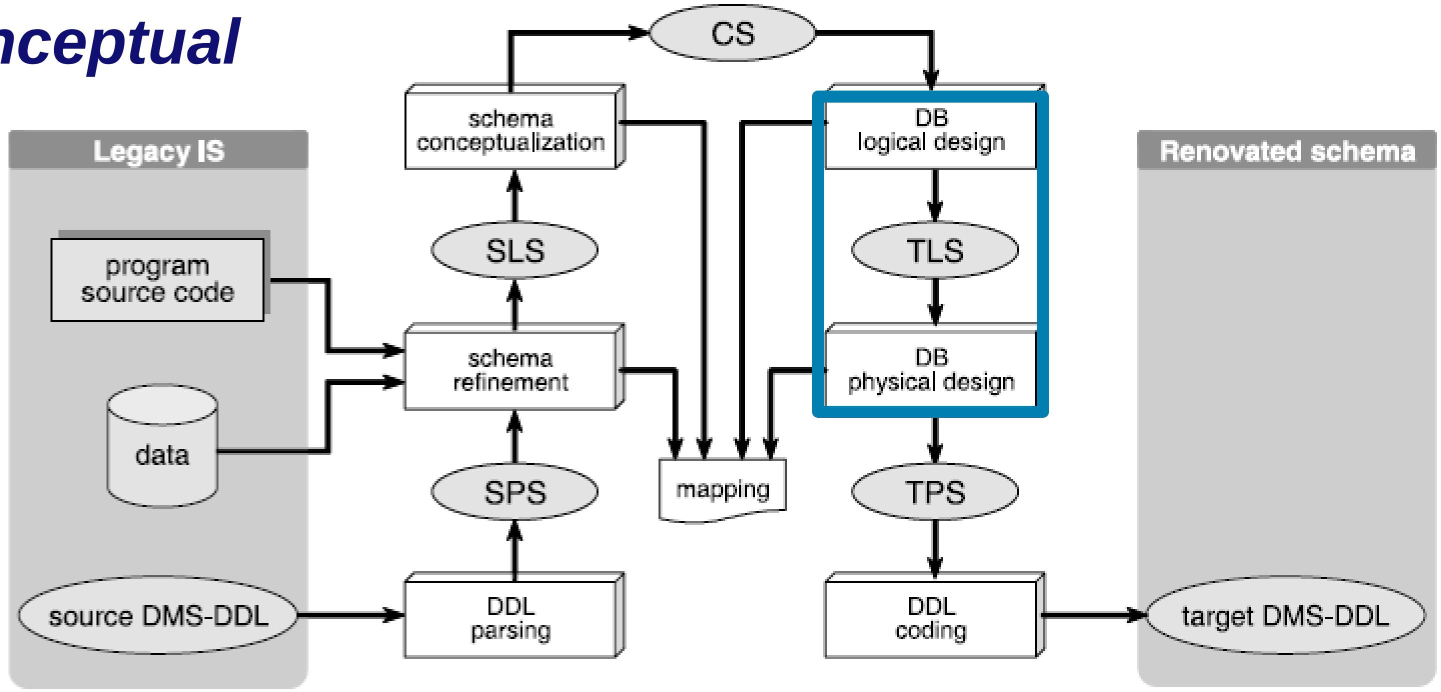
# Conceptual normalization

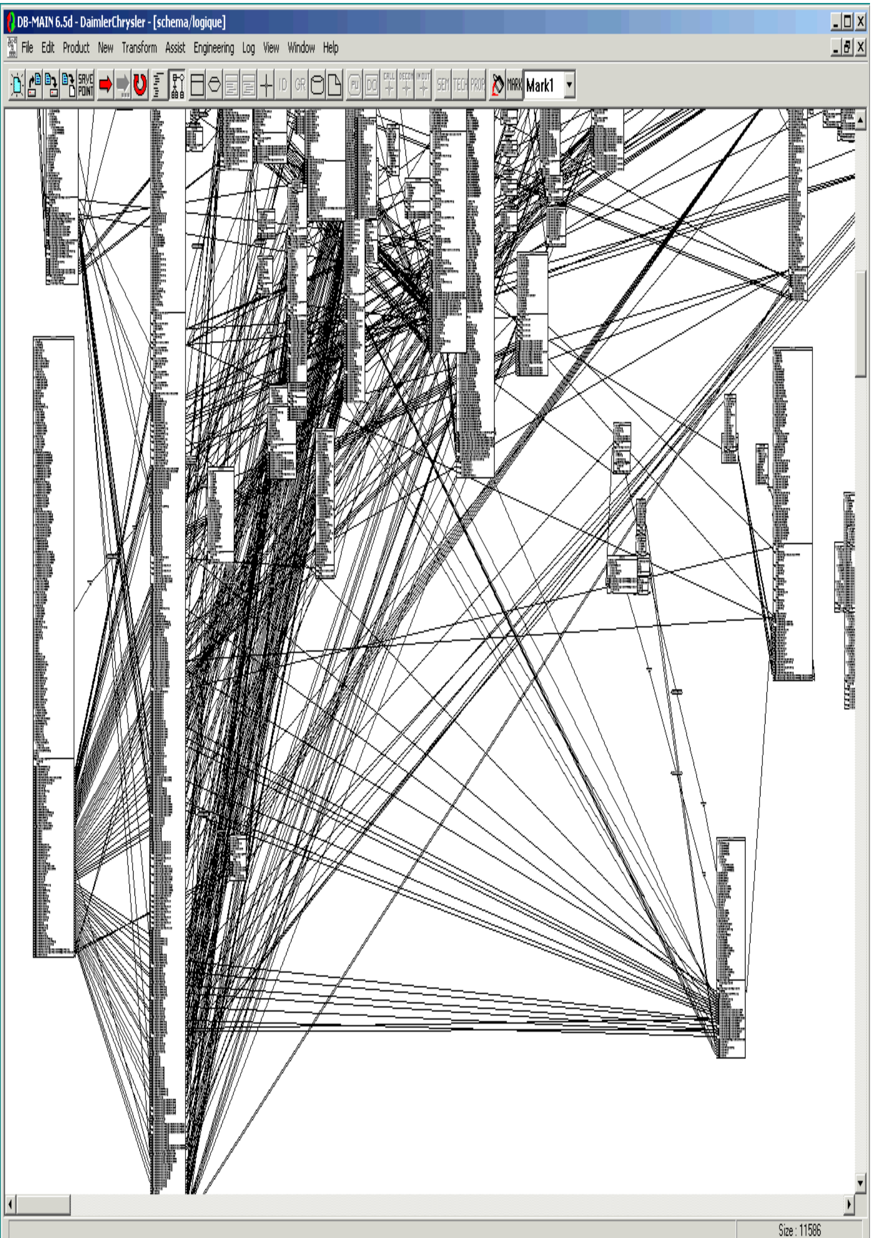


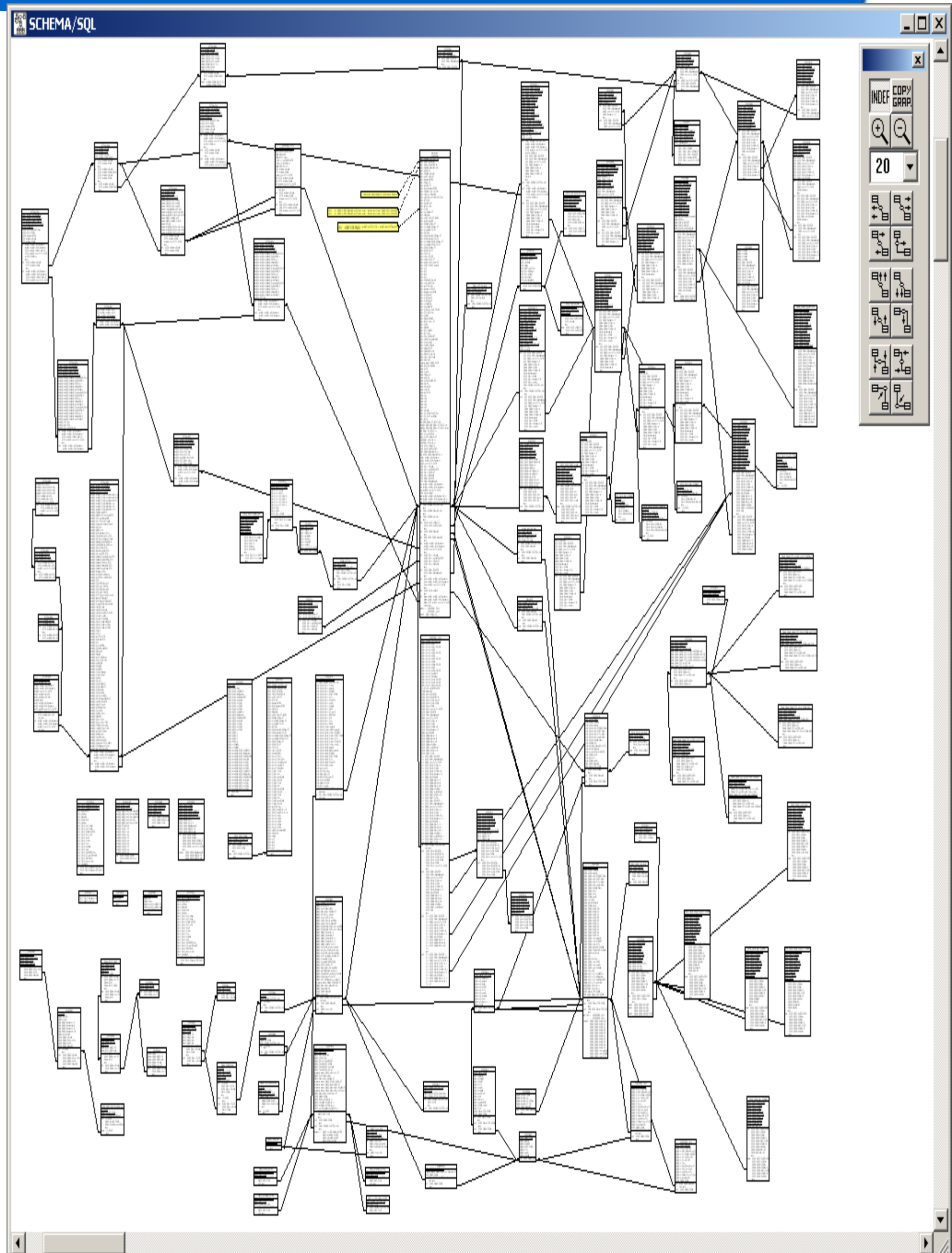
# Conceptual




- **Logical design: schema concepts ⇒ DB tables**
- **Physical design: e.g., naming conventions**

# Hainaut 2009: Before and After



# Another case study (Ch. 6)

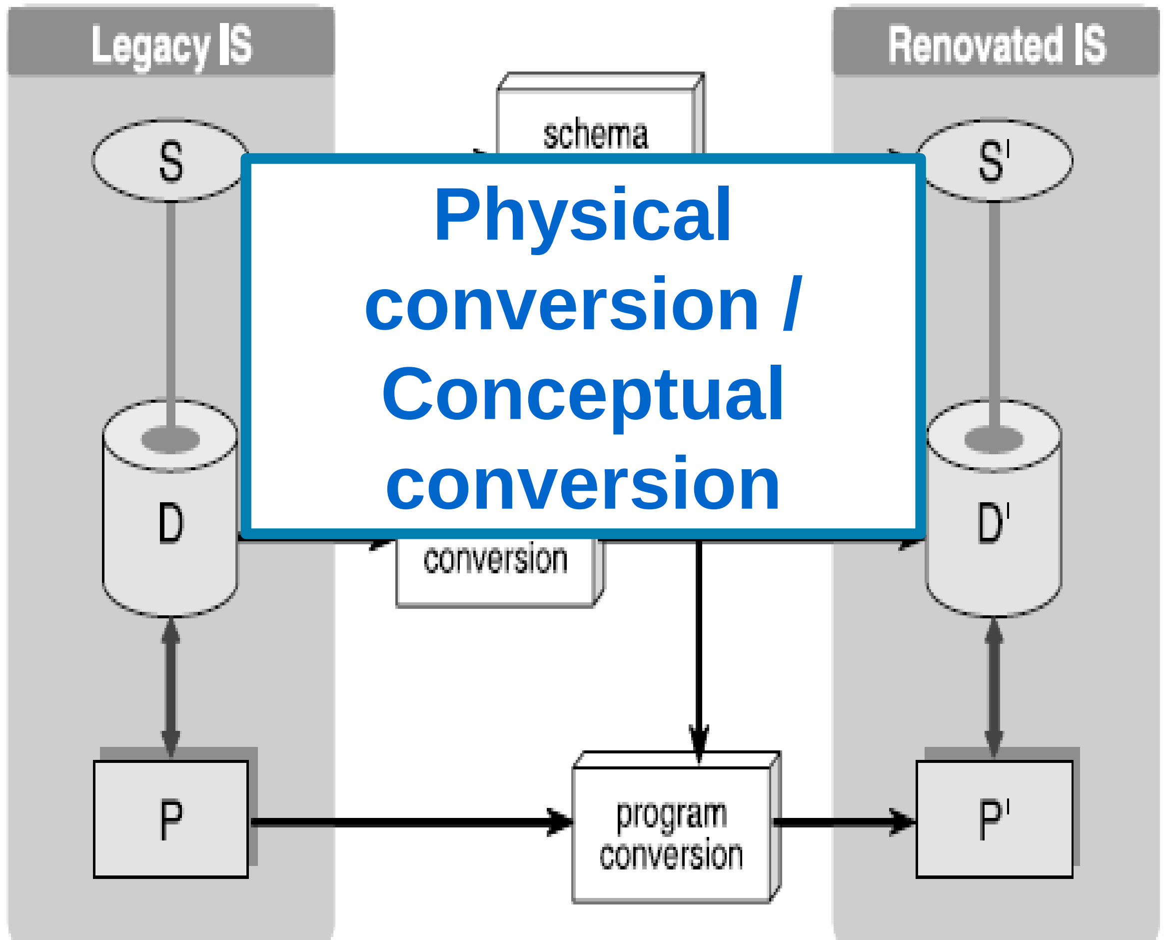
| | Physical IDS/II | Refined IDS/II | Conceptual | Relational DB2 |
|---|---|---|---|---|
| # entity types | 159 | 159 | 156 | 171 |
| # relationship types | 148 | 148 | 90 | 0 |
| # attributes | 458 | 9 027 | 2 176 | 2 118 |
| max # att./entity type | 8 | 104 | 61 | 94 |

- **Refined schema: decomposed attributes**
  - **Address = Street, Number, City, ZIP, State**
- **Schema refinement:**
  - **89 foreign keys, 37 computed foreign keys, 60 redundancies**
- **Relational DB2**
  - **↑entities: decomposition of arrays**

# Recall…

- **So far we have considered DB schemas only**

- **Next step: data migration**



# Data migration

- **Strategy depends on the schema migration strategy**

- **Physical conversion: straightforward**
  - **Data format conversion**

- **Conceptual conversion**
  - **Data may violate implicit constraints**
  - **Hence, data cleaning is required as preprocessing**
  - **Once the data has been cleaned up: akin to physical conversion**



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# What should be cleaned? 1 source [Rahm, Do]

- **Schema-level**
  - **Can be solved with appropriate integrity constraints**

| Scope/Problem | | Dirty Data | Reasons/Remarks |
|---|---|---|---|
| Attribute | Illegal values | bdate=30.13.70 | values outside of domain range |
| Record | Violated attribute dependencies | age=22, bdate=12.02.70 | age = (current date – birth date) should hold |
| Record type | Uniqueness violation | $emp_1$=(name="John Smith", SSN="123456")<br>$emp_2$=(name="Peter Miller", SSN="123456") | uniqueness for SSN (social security number) violated |
| Source | Referential integrity violation | emp=(name="John Smith", deptno=127) | referenced department (127) not defined |

- **Instance-level**

| Scope/Problem | | Dirty Data | Reasons/Remarks |
|---|---|---|---|
| Attribute | Missing values | phone=9999-999999 | unavailable values during data entry (dummy values or null) |
| | Misspellings | city="Liipzig" | usually typos, phonetic errors |
| | Cryptic values, Abbreviations | experience="B";<br>occupation="DB Prog." | |
| | Embedded values | name="J. Smith 12.02.70 New York" | multiple values entered in one attribute (e.g. in a free-form field) |
| | Misfielded values | city="Germany" | |
| Record | Violated attribute dependencies | city="Redmond", zip=77777 | city and zip code should correspond |
| Record type | Word transpositions | $name_1$= "J. Smith", $name_2$="Miller P." | usually in a free-form field |
| | Duplicated records | $emp_1$=(name="John Smith",...);<br>$emp_2$=(name="J. Smith",...) | same employee represented twice due to some data entry errors |
| | Contradicting records | $emp_1$=(name="John Smith", bdate=12.02.70);<br>$emp_2$=(name="John Smith", bdate=12.12.70) | the same real world entity is described by different values |
| Source | Wrong references | emp=(name="John Smith", deptno=17) | referenced department (17) is defined but wrong |

# What should be cleaned? Multiple sources

- **Which DB tuples refer to the same real-world entity?**

*Customer* (source 1)

| *CID* | *Name* | *Street* | *City* | *Sex* |
|---|---|---|---|---|
| 11 | Kristen Smith | 2 Hurley Pl | South Fork, MN 48503 | 0 |
| 24 | Christian Smith | Hurley St 2 | S Fork MN | 1 |

*Client* (source 2)

| *Cno* | *LastName* | *FirstName* | *Gender* | *Address* | *Phone/Fax* |
|---|---|---|---|---|---|
| 24 | Smith | Christoph | M | 23 Harley St, Chicago IL, 60633-2394 | 333-222-6542 / 333-222-6599 |
| 493 | Smith | Kris L. | F | 2 Hurley Place, South Fork MN, 48503-5998 | 444-555-6666 |

*Customers* (integrated target with cleaned data)

| *No* | *LName* | *FName* | *Gender* | *Street* | *City* | *State* | *ZIP* | *Phone* | *Fax* | *CID* | *Cno* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Smith | Kristen L. | F | 2 Hurley Place | South Fork | MN | 48503-5998 | 444-555-6666 | | 11 | 493 |
| 2 | Smith | Christian | M | 2 Hurley Place | South Fork | MN | 48503-5998 | | | 24 | |
| 3 | Smith | Christoph | M | 23 Harley Street | Chicago | IL | 60633-2394 | 333-222-6542 | 333-222-6599 | | 24 |

- **Scheme: name and structure conflicts**
- **Instance: data representation, duplication, identifiers**

# How to clean up data?

- Analyse:
  - Define inconsistencies and detect them
- Define individual transformations and the workflow
- Verify correctness and effectiveness
  - Sample/copy of the data
- Transform
- Backflow if needed
  - If the "old" data still will be used, it can benefit from the improvements.

# Data cleaning: Analysis

- **Data profiling**
  - **Instance analysis of individual attributes**
  - **Min, max, distribution, cardinality, uniqueness, null values**
    - **max(age) > 150? count(gender) > 2?**

- **Data mining**
  - **Instance analysis of relations between the attributes**
  - **E.g., detect association rules**
    - **Confidence(A $\Rightarrow$ B) = 99%**
    - **1% of the cases might require cleaning**

# Data cleaning: Analysis (continued)

- Record matching problem:
  - Smith Kris L., Smith Kristen L., Smith Christian, …
- Matching based on
  - Simplest case: unique identifiers (primary keys)
  - Approximate matching
    - Different weights for different attributes
    - Strings:
      - Edit distance
      - Keyboard distance
      - Phonetic similarity
    - Very expensive for large data sets

# Define data transformations

- Use transformation languages
  - Proprietary (e.g., DataTransformationService of Microsoft)
  - SQL extended with user-defined functions (UDF):

```
CREATE VIEW Customer2(LName, FName, Street, CID) AS
SELECT LastNameExtract(Name),
       FirstNameExtract(Name),
       Street, CID)
FROM Customer

CREATE FUNCTION LastNameExtract(Name VARCHAR(255))
  RETURNS VARCHAR(255)
  RETURN SUBSTRING(Name FROM 28 FOR 15)
```

# UDF: advantages and disadvantages

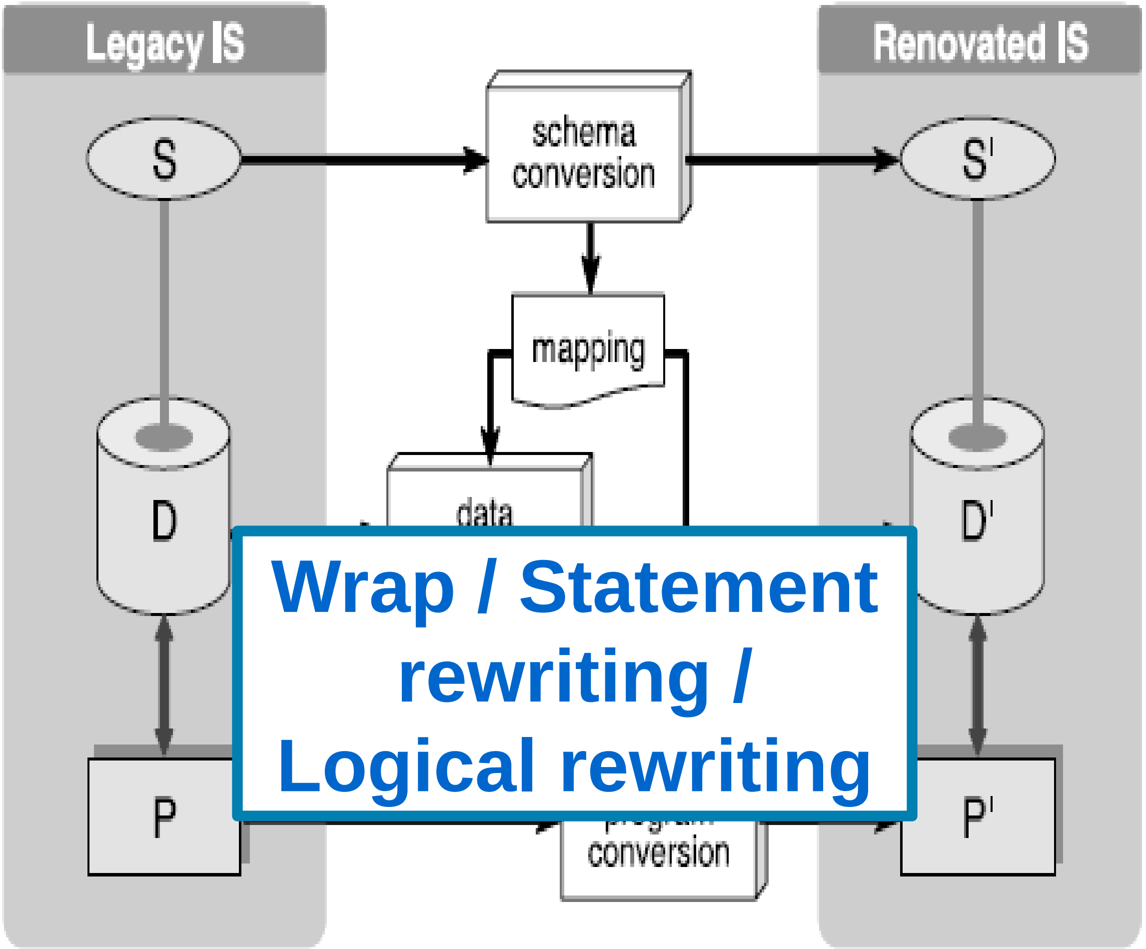
- Advantages
  - Does not require learning a separate language
- Disadvantages
  - Suited only for information already in a DB
    - What about COBOL files?
  - Ease of programming depends on availability of specific functions in the chosen SQL dialect
    - Splitting/merging are supported but have to be reimplemented for every separate field
    - Folding/unfolding of complex attributes not supported at all.

# Inconsistency resolution

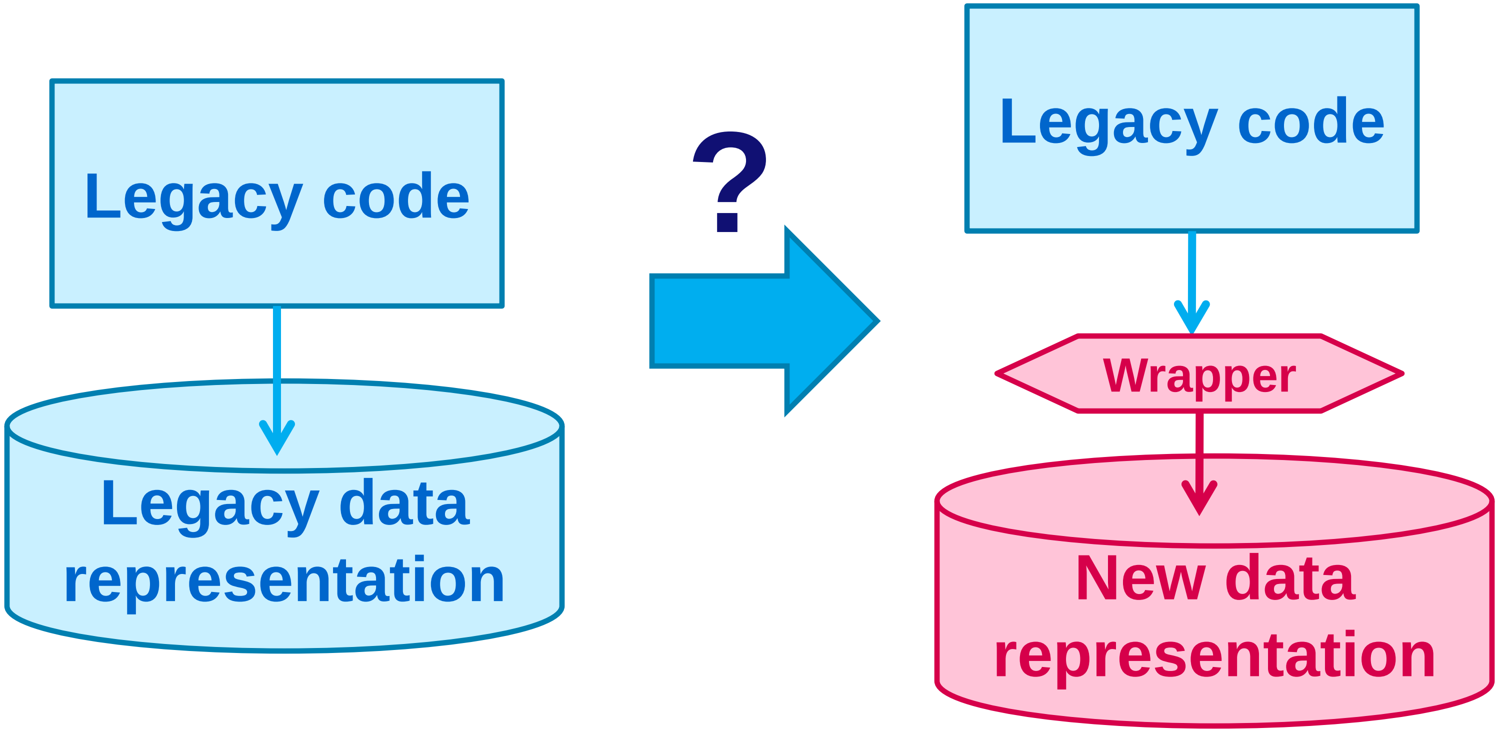
- If inconsistency has been detected, the offending instances
  - Are removed
  - Are modified so the offending data becomes NULL
  - Are modified by following user-defined preferences
    - One table might be more reliable than the other
    - One attribute may be more reliable than the other
  - Are modified to reduce the (total) number of modifications required to restore consistency

# From data to programs

- **So far: schemas and data**
- **Next : programs**
  - **Wrapping**
  - **Statement rewriting**
  - **Program rewriting**



# Wrappers


Legacy code
Legacy data representation
?
Legacy code
Wrapper
New data representation

# Wrappers

- Replace "standard" OPEN, CLOSE, READ, WRITE with wrapped operations

```
DELETE-CUS-ORD.
   MOVE C-CODE TO O-CUST.
   MOVE 0 TO END-FILE.
   READ ORDERS KEY IS O-CUST
     INVALID KEY MOVE 1 TO END-FILE.
   PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

Actual implementation of "READ"

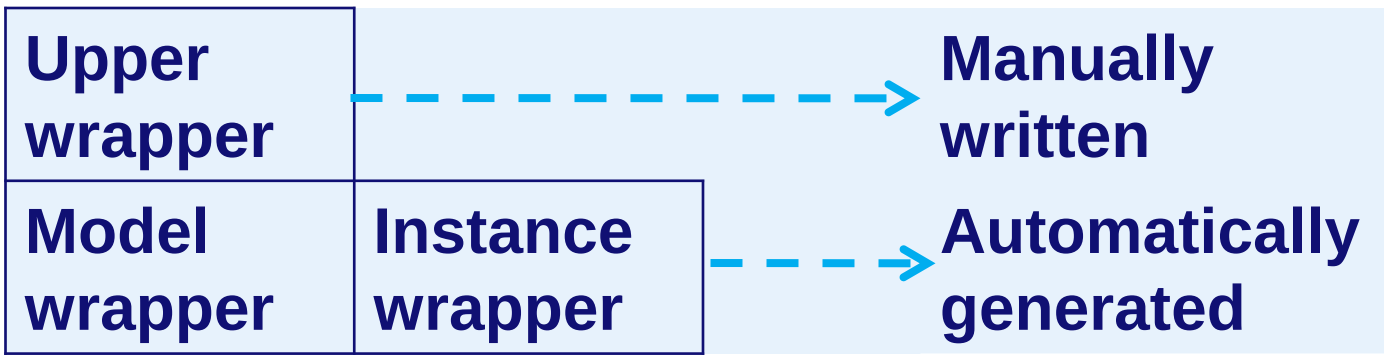
Start wrapping action "READ"

```
DELETE-CUS-ORD.
   MOVE C-CODE TO O-CUST.
   MOVE 0 TO END-FILE.
   SET WR-ACTION-READ TO TRUE.
   MOVE "KEY IS O-CUST" TO WR-OPTION.
   CALL WR-ORDERS USING WR-ACTION, ORD, WR-OPTION, WR-STATUS
   IF WR-STATUS-INVALID-KEY MOVE 1 TO END-FILE.
   PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

# Wrappers

- **[Thiran, Hainaut]: wrapper code can be reused**

**Cannot be expressed in the DB itself**




**Common to all DMS in the family: cursor, transaction**

**Specific to the given DB: query translation, access optimization**

# Wrapping: Pro and Contra

- Wrapping
  - Preserves logic of the legacy system
  - Can be (partially) automated
- Physical + wrapper:
  - Almost automatic (cheap and fast)
  - Quality is poor, unless the legacy DB is well-structured
- Conceptual + wrapper:
  - More complex/expensive
  - Quality is reasonable: “First schema, then – code”
  - Possible performance penalty due to complexity of wrappers
    - Mismatch: “DB-like” schema and “COBOL like” code

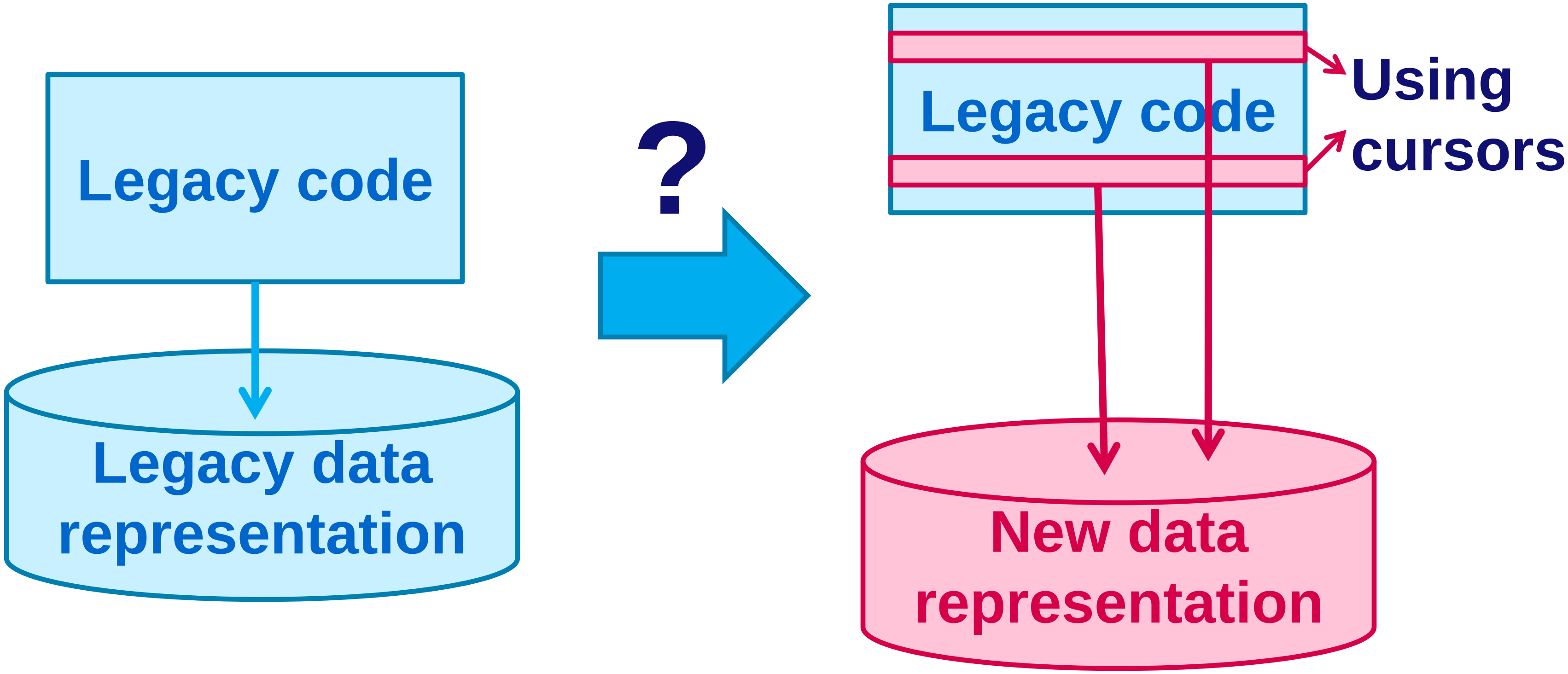
# Wrapping in practice

Table 6.2. Program transformation results

| | Migrated | Manually transformed |
|---|---|---|
| # programs | 669 | 17 |
| # copybooks | 3 917 | 68 |
| # IDS/II verbs | 5 314 | 420 |

- **Wrappers**
  - **159 wrappers**
  - **450 KLOC**

# Statement rewriting



# Cursor?..

- **Control structure for the successive traversal of records in a query result**

- **Cursor declaration**

```
EXEC SQL DECLARE CURSOR ORD_GE_K1 FOR
  SELECT CODE, CUS_CODE
  FROM ORDERS WHERE CUS_CODE >= :O-CUST
  ORDER BY CUS_CODE
END-EXEC.
```

- **What will this cursor return? O_CUST = J12**

| CUS_CODE | CODE |
|---|---|
| J11 | 12 |
| J12 | 11 |
| J13 | 14 |
| K01 | 15 |

**Why would you like to use such a cursor?**

```
READ ORDERS KEY IS O-CUST
```

**COBOL READ: Sequential reading starting from the first tuple with the given key**

# Cursor?..

- **Control structure for the successive traversal of records in a query result**

  - **Cursor declaration**

```
EXEC SQL DECLARE CURSOR ORD_GE_K1 FOR
  SELECT CODE, CUS_CODE
  FROM ORDERS WHERE CUS_CODE >= :O-CUST
  ORDER BY CUS_CODE
END-EXEC.
```

  - **Opening a cursor**

```
EXEC SQL OPEN ORD_GE_K1 END-EXEC
```

  - **Retrieving data**

```
EXEC SQL
  FETCH ORD_GE_K1
  INTO :O-CODE, :O-CUST
END-EXEC
```

  - **Closing cursor**

# Statement rewriting

- **Replace "standard" OPEN, CLOSE, READ, WRITE with explicit SQL operations**

```
DELETE-CUS-ORD.
   MOVE C-CODE TO O-CUST.
   MOVE 0 TO END-FILE.
   READ ORDERS KEY IS O-CUST
     INVALID KEY MOVE 1 TO END-FILE.
   PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

```
DELETE-CUS-ORD.
  MOVE C-CODE TO O-CUST.
  MOVE 0 TO END-FILE.
  EXEC SQL
    SELECT COUNT(*) INTO :COUNTER
    FROM ORDERS WHERE CUS_CODE = :O-CUST
  END-EXEC.
  IF COUNTER = 0
     MOVE 1 TO END-FILE
  ELSE
     EXEC SQL OPEN ORD_GE_K1 END-EXEC
     MOVE "ORD_GE_K1" TO ORD-SEQ
     EXEC SQL
       FETCH ORD_GE_K1
       INTO :O-CODE, :O-CUST
     END-EXEC
     IF SQLCODE NOT = 0
        MOVE 1 TO END-FILE
     ELSE
        EXEC SQL OPEN ORD_DETAIL END-EXEC
        SET IND-DET TO 1
        MOVE 0 TO END-DETAIL
        PERFORM FILL-ORD-DETAIL UNTIL END-DETAIL = 1
     END-IF
  END-IF.
  PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

# Statement rewriting

- **Replace "standard" OPEN, CLOSE, READ, WRITE with explicit SQL operations**

```
DELETE-CUS-ORD.

   READ ORDERS KEY IS O-CUST
     INVALID KEY MOVE 1 TO END-FILE.
```

**O-CUST does not appear in ORDERS**

```
DELETE-CUS-ORD.

  EXEC SQL
    SELECT COUNT(*) INTO :COUNTER
    FROM ORDERS WHERE CUS_CODE = :O-CUST
  END-EXEC.
  IF COUNTER = 0
     MOVE 1 TO END-FILE
  ELSE
     EXEC SQL OPEN ORD_GE_K1 END-EXEC
     MOVE "ORD_GE_K1" TO ORD-SEQ
     EXEC SQL
       FETCH ORD_GE_K1
       INTO :O-CODE, :O-CUST
     END-EXEC
     IF SQLCODE NOT = 0
        MOVE 1 TO END-FILE
     ELSE
        EXEC SQL OPEN ORD_DETAIL END-EXEC
        SET IND-DET TO 1
        MOVE 0 TO END-DETAIL
        PERFORM FILL-ORD-DETAIL UNTIL END-DETAIL = 1
     END-IF
  END-IF.
```

# Statement rewriting

- Replace "standard" OPEN, CLOSE, READ, WRITE with explicit SQL operations

```
DELETE-CUS-ORD.

   READ ORDERS KEY IS O-CUST
```

- Files can have multiple keys and multiple READ commands

- We need to remember which key/READ is used!

```
IF ORD-SEQ = "ORD_GE_K1"
   EXEC SQL
     FETCH ORD_GE_K1 INTO :O-CODE,:O-CUST
   END-EXEC
```

```
DELETE-CUS-ORD.

     EXEC SQL OPEN ORD_GE_K1 END-EXEC
     MOVE "ORD_GE_K1" TO ORD-SEQ
     EXEC SQL
       FETCH ORD_GE_K1
       INTO :O-CODE, :O-CUST
     END-EXEC
     IF SQLCODE NOT = 0
        MOVE 1 TO END-FILE
     ELSE
        EXEC SQL OPEN ORD_DETAIL END-EXEC
        SET IND-DET TO 1
        MOVE 0 TO END-DETAIL
        PERFORM FILL-ORD-DETAIL UNTIL END-DETAIL = 1
     END-IF
```

# Statement rewriting

- **Replace "standard" OPEN, CLOSE, READ, WRITE with explicit SQL operations**

```
DELETE-CUS-ORD.

   READ ORDERS KEY IS O-CUST
```

- **Prepare the cursor for READing**
- **READ the data**

```
DELETE-CUS-ORD.

        EXEC SQL OPEN ORD_GE_K1 END-EXEC

        EXEC SQL
          FETCH ORD_GE_K1
          INTO :O-CODE, :O-CUST
        END-EXEC
        IF SQLCODE NOT = 0
           MOVE 1 TO END-FILE
        ELSE
           EXEC SQL OPEN ORD_DETAIL END-EXEC
           SET IND-DET TO 1
           MOVE 0 TO END-DETAIL
           PERFORM FILL-ORD-DETAIL UNTIL END-DETAIL = 1
        END-IF
```

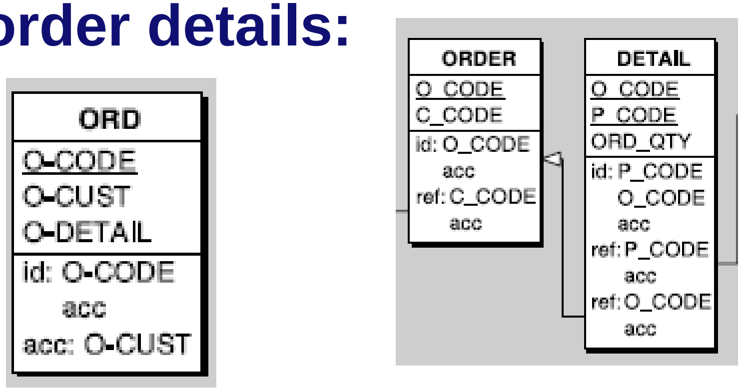
# Statement rewriting

- **Replace "standard" OPEN, CLOSE, READ, WRITE with explicit SQL operations**

```
DELETE-CUS-ORD.

   READ ORDERS KEY IS O-CUST
```

- **We need additional cursor and procedure to read the order details:**




**Legacy DB** **New DB**

```
DELETE-CUS-ORD.

    EXEC SQL OPEN ORD_GE_K1 END-EXEC

    EXEC SQL
      FETCH ORD_GE_K1
      INTO :O-CODE, :O-CUST
    END-EXEC
    IF SQLCODE NOT = 0
       MOVE 1 TO END-FILE
    ELSE
       EXEC SQL OPEN ORD_DETAIL END-EXEC
       SET IND-DET TO 1
       MOVE 0 TO END-DETAIL
       PERFORM FILL-ORD-DETAIL UNTIL END-DETAIL = 1
    END-IF
```

# Statement rewriting: Pro and Contra

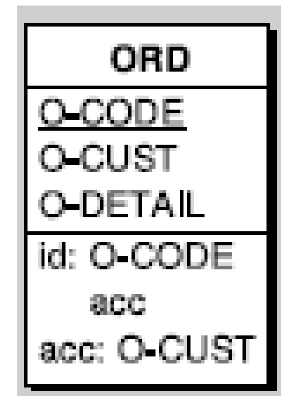
- Statement rewriting
  - Preserves logic of the legacy system
  - Intertwines legacy code with new access techniques
  - Detrimental for maintainability
- Physical + statement
  - Inexpensive and popular
  - Blows up the program: from 390 to ~1000 LOC
  - Worst strategy possible
- Conceptual + statement
  - Good quality DB, unreadable code: “First schema, then – code”
  - Meaningful if the application will be rewritten on the short term

# Alternative 3: Logic Rewriting

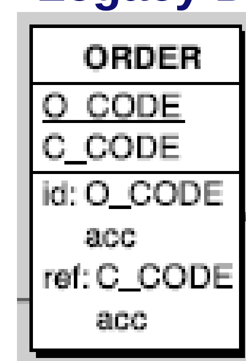
- **Akin to conceptual conversion**
  - **e.g., COBOL loop ⇒ SQL join**
  - **And meaningful only in combination with it**
    - **Otherwise: high effort with poor results**

```
DELETE-CUS-ORD.
   MOVE C-CODE TO O-CUST.
   MOVE 0 TO END-FILE.
   READ ORDERS KEY IS O-CUST
     INVALID KEY MOVE 1 TO END-FILE.
   PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

```
DELETE-CUS-ORD.
   EXEC SQL
     DELETE FROM ORDERS
     WHERE CUS_CODE = :C-CODE
   END-EXEC.
   IF SQLCODE NOT = 0 THEN GO TO ERR-DEL-ORD.
```




Legacy DB




New DB

# Alternative 3: Logic Rewriting

- Manual transformation with automatic support
  - Identify file access statements
  - Identify and understand data and statements that depend on these statements
  - Rewrite these statements and redefine the objects

```
DELETE-CUS-ORD.
    MOVE C-CODE TO O-CUST.
    MOVE 0 TO END-FILE.
    READ ORDERS KEY IS O-CUST
       INVALID KEY MOVE 1 TO END-FILE.
    PERFORM DELETE-ORDER UNTIL END-FILE = 1.
```

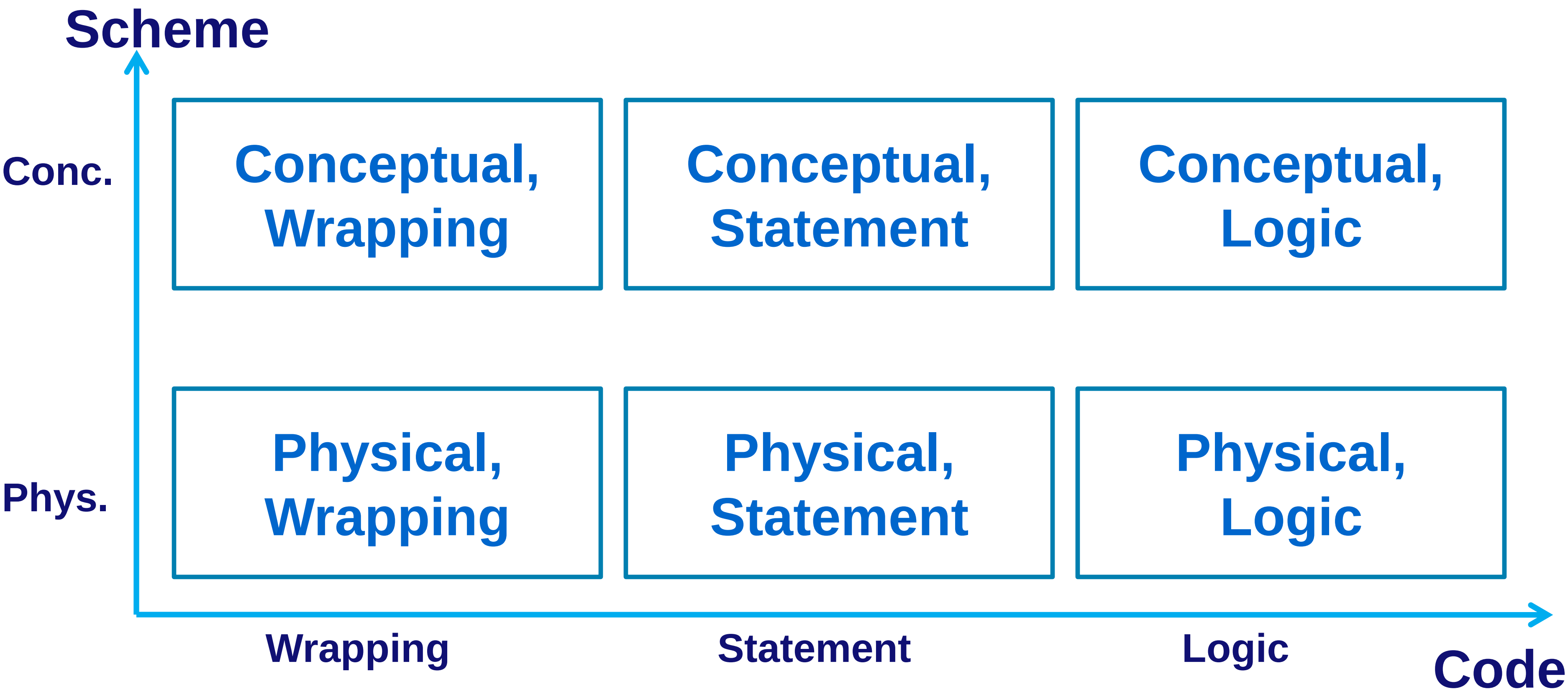
```
DELETE-CUS-ORD.
    EXEC SQL
       DELETE FROM ORDERS
       WHERE CUS_CODE = :C-CODE
    END-EXEC.
    IF SQLCODE NOT = 0 THEN GO TO ERR-DEL-ORD.
```

# Logic rewriting: Pro and Contra

- Logic rewriting + physical
  - Low quality DB
  - High costs due to logic rewriting
  - Unfeasible
- Logic rewriting + conceptual
  - High quality
  - Highest costs

# Putting it all together

- All combinations are possible
- Not all are desirable



# Putting it all together

- **All combinations are possible**
- **Not all are desirable**

| Scheme ↑ / Code → | Wrapping | Statement | Logic |
|---|---|---|---|
| **Conc.** | Better DB, performance penalty | Better DB, the application is rewritten later | Best but also $$$ |
| **Phys.** | Zero time | Popular, $, Bad | Very bad, $$ |

# Tools

- **DB-MAIN CASE tool (University of Namur, ReVeR)**
  - **DDL extraction**
  - **Schema storage, analysis and manipulation**
  - **Implicit constraint validation**
  - **Schema mapping management**
  - **Data analysis & migration**
  - **Wrapper generation (COBOL-to-SQL, CODASYL-to-SQL)**
- **Transformations**
  - **Eclipse Modelling Framework: ATL**
  - **ASF+SDF Meta-Environment (CWI, Amsterdam)**

# Conclusions

- 3 levels of DB migration: schema, data, code

- Schema: physical/conceptual
- Data: determined by schema
- Code: wrapper/statement rewriting/logical rewriting

- Popular but bad: physical + statement
- Expensive but good: conceptual + logic
- Alternatives to consider:
  - conceptual + wrapping/statement
  - physical + wrapping (zero time)