Representing Data Elements

Physical Layout of Data

In relational terms:

- Field = sequence of bytes representing the value of an attribute in a tuple.
- Record = sequence of bytes divided into fields, representing a tuple.
- File = collection of blocks used to hold a relation = set of tuples or records, respectively.

In object-oriented terms:

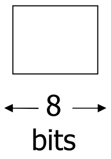
- Field represents an attribute or relationship.
- Record represents an object.
- File represents extent of a class.

The Mapping Problem

What are the data items we want to store?

- a salary
- a name
- a date
- a picture

⇨ What we have available: Bytes



Numbers

Integer: 2/4 bytes

e.g., 35 is

00000000 00100011

- Real, floating point
  n bits for mantissa, *m* for exponent….

Characters

→ various coding schemes suggested,
most popular is ascii

<u>Example:</u>

A:	1000001
a:	1100001
5:	0110101
LF:	0001010

Boolean Values

Boolean

e.g., TRUE	1111 1111
FALSE	0000 0000

Application specific Enumerations

e.g., RED → 1 GREEN → 3
BLUE → 2 YELLOW → 4 …

⇨ Can we use less than 1 byte/code?

Yes, but only if desperate...

Date and Time

Dates

e.g.: - Integer, # days since Jan 1, 1900
- 8 characters, YYYYMMDD
(not YYMMDD!)
- 7 characters, YYYYDDD
- SQL: YYYY-MM-DD

Time

e.g. - Integer, seconds since midnight
- characters, HHMMSSFF

Strings of Characters

- Null terminated
  e.g.,

c	a	t	\0	☒	

- Length given
  e.g.,

3	c	a	t	☒		

- Fixed length

Records

Consider fixed-length records first

Record the consists of

- Space for each field of the record.
  - Sometimes, it is required to align fields starting at a multiple of 4 or 8.

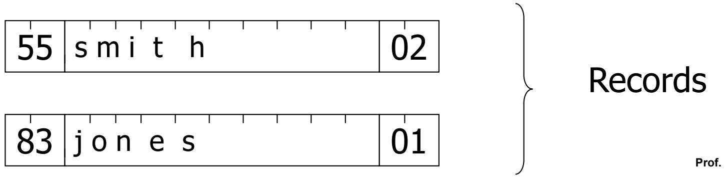
Example: Employee record

(1) E#, 2 byte integer

(2) E_name, 10 char.

(3) Dept, 2 byte code

Schema



55	s m i t h	02
83	j o n e s	01

Records

Record Header

Usually the fields of the record are preceded by a header

Header = space for information about the record, e.g.,

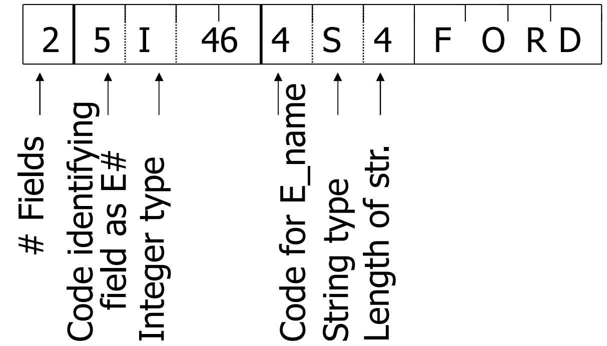
- record format (pointer to schema),
- record length,
- timestamp.

Variable-Length Records

Can occur in case of

- Fields that vary in length
- Repeating fields, e.g., a set of pointers represent a manymany relationship
- Variableformat records: field names are arbitrary
  - Important for selfdescribing data, information integration.

Example: variable format and length



2	5	I	46	4	S	4	F O R D

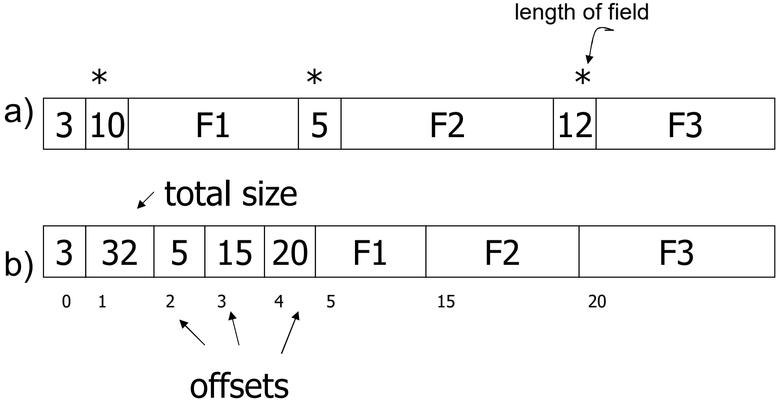
Field name codes could also be strings, i.e. TAGS

Example: Repeating Fields

Employee has one or more children

3	E_name: Fred	Child: Sally	Child: Tom

Internal Organization of Record



Strategy a) Each field is preceded by a number providing its length

Strategy b) The Record header contains a set of pointers to the variable length fields

Hybrid Format

Hybrid format

- one part is fixed, other variable

E.g.: All employees have E#, name, dept

other fields vary.

25	Smith	Toy	2	Hobby:chess	state:retired

# of var fields

Alternative realization

- Split Records Into Fixed/Variable Parts
- Fixed part has a pointer to space where current value of variable fields can be found.

Placing Records into Blocks

Structure of Blocks:

1. Block header = space for info such as:
   - Links to other blocks of a data structure.
   - Role info for this block, e.g., for which relation does the block hold tuples?
   - Directory of records in the block.
   - Block ID.
   - Timestamp.
2. Some number of records

Options for storing records in blocks

(1) separating records

(2) spanned vs. unspanned

(3) mixed record types – clustering

(4) split records

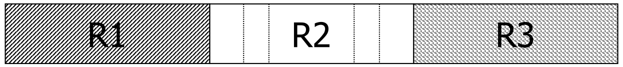
(5) sequencing

(6) addressing

Separating records

When does a record ends and the next starts?

Block



(a) no need to separate - fixed size recs.

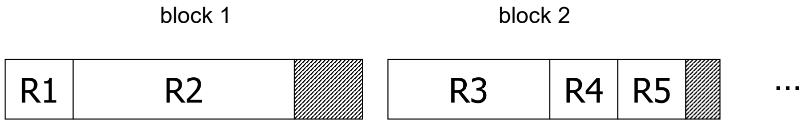
(b) special marker

(c) give record lengths (or offsets)

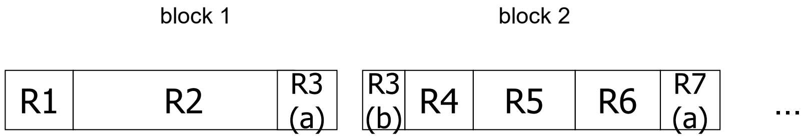
- within each record
- in block header

Spanned vs. Unspanned

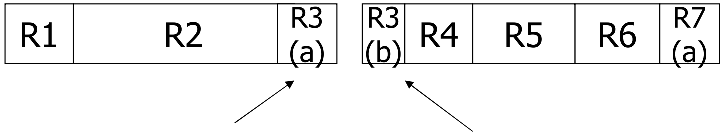
Unspanned: records must be within one block



A spanned record can be divided between two blocks



Spanned records



need indication
of partial record
+ “pointer” to rest

need indication
of continuation

Spanned vs. Unspanned

Unspanned is much simpler, but may waste space…

Spanned essential if

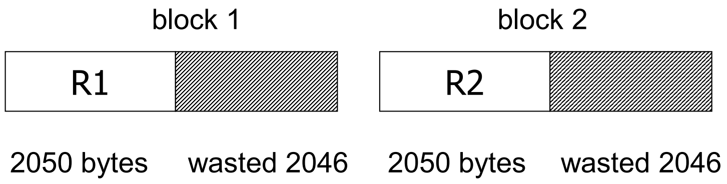
record size > block size

Example

10^6 records

each of size 2,050 bytes (fixed)

block size = 4096 bytes



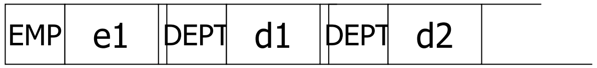
Total wasted $\approx 2 \times 10^9$ Utilization $\approx$ 50%

Total space $\approx 4 \times 10^9$

Mixed record types

Mixed: records of different types (e.g. EMPLOYEE, DEPT) allowed in same block

e.g., a block



Why do we want to mix?

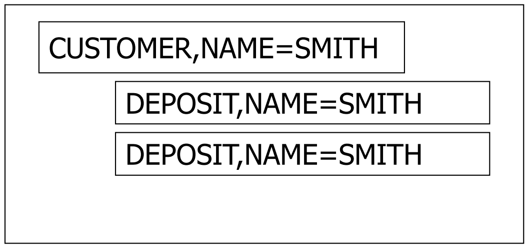
Answer: CLUSTERING

Records that are frequently accessed together should be in the same block

Example

Q1: select A#, C_NAME, C_CITY, …
from DEPOSIT, CUSTOMER
where DEPOSIT.C_NAME =
CUSTOMER.C.NAME

a block



Options for storing records in blocks

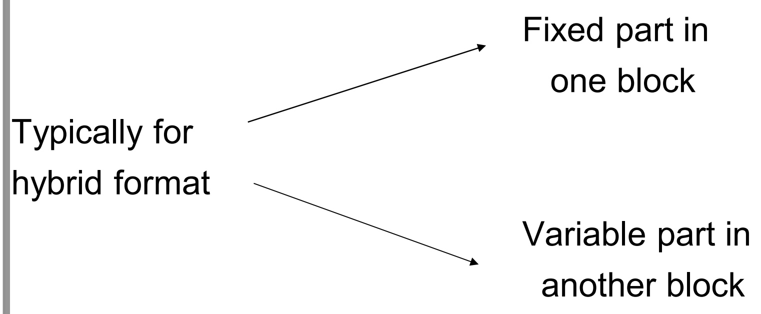
If Q1 frequent, clustering is good

But if Q2 frequent

```
Q2:   SELECT *
        FROM CUSTOMER
```

CLUSTERING IS COUNTER PRODUCTIVE

Split records



Typically for hybrid format

Fixed part in one block

Variable part in another block

Sequencing

Ordering records in file (and block) by some key value

⇒ sequential file

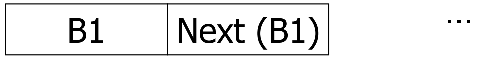
Why sequencing?

Typically to make it possible to efficiently read records in order

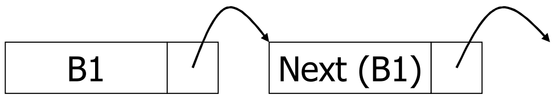
- e.g., to do a merge-join — discussed later

Sequencing Options (1)

(a) Next block physically contiguous



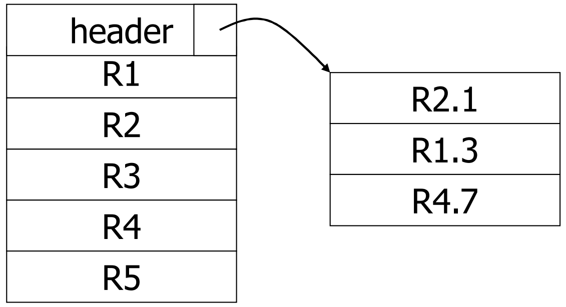
(b) Linked



Sequencing Options (2)

(c) Overflow area

Records
in sequence



Addressing

How does one refer to records?

Two approaches:

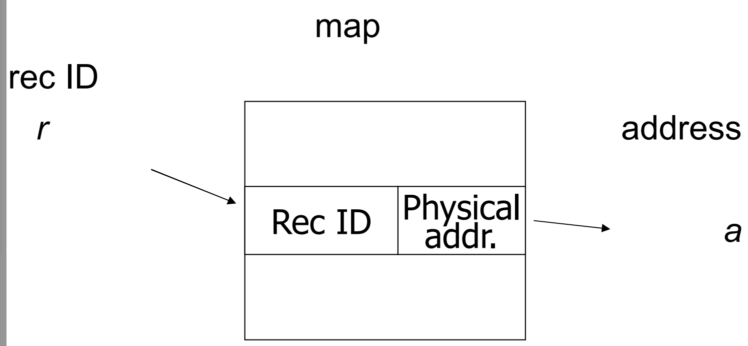
1. Physical: sequence of bytes describing location

For example in case of a HDD: device ID, cylinder #, surface #, block # within track, offset within block (for records).

2. Logical (indirect): a map table associates abstract ID's, perhaps fixed-length character strings, with physical addresses.

Fully Indirect

E.g., Record ID is arbitrary bit string



Addressing (Cont.)

The map table is itself a relation; Fast access is important.

Physical addresses are more efficient.

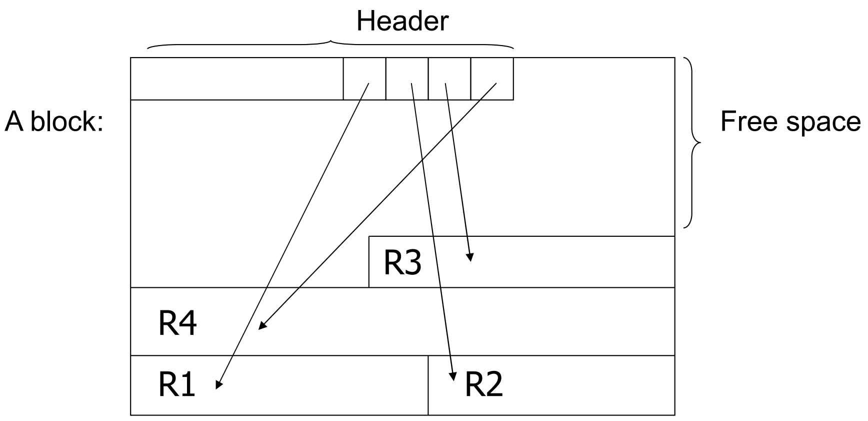
Logical addresses allow flexibility:

- records can move or be deleted without dangling pointers.

Common compromise: physical to block level, table of record offsets within blocks.

- Tuple-Identifier (TID)
- movement within block: references remain unchanged; only table is modified
- movement to different block: original block contains another TID instead of the record
- regular reorganizations necessary

Indirection in Block



Header

A block:

Free space

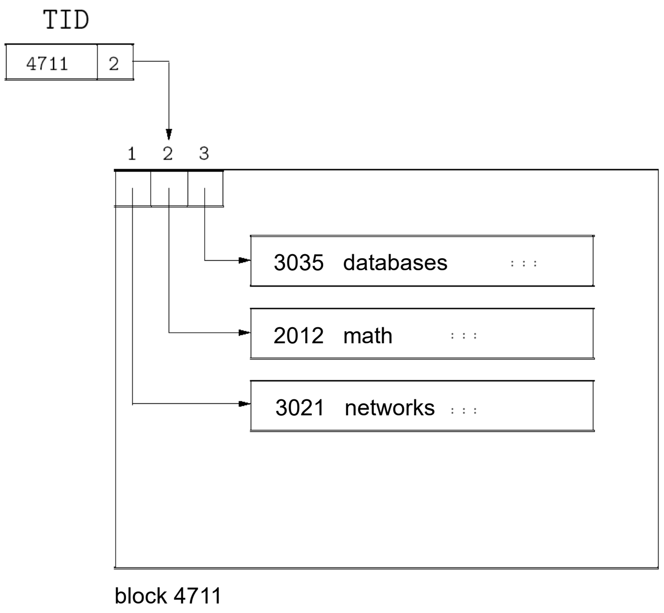
R3

R4

R1

R2

TID Example



TID

4711 2

1 2 3

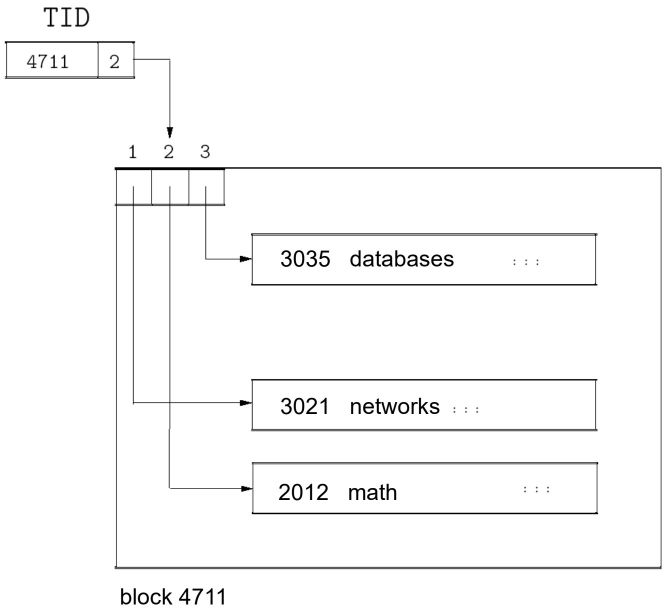
3035 databases . . .

2012 math . . .

3021 networks . . .

block 4711

Movement Within Block



TID

4711 2

1 2 3

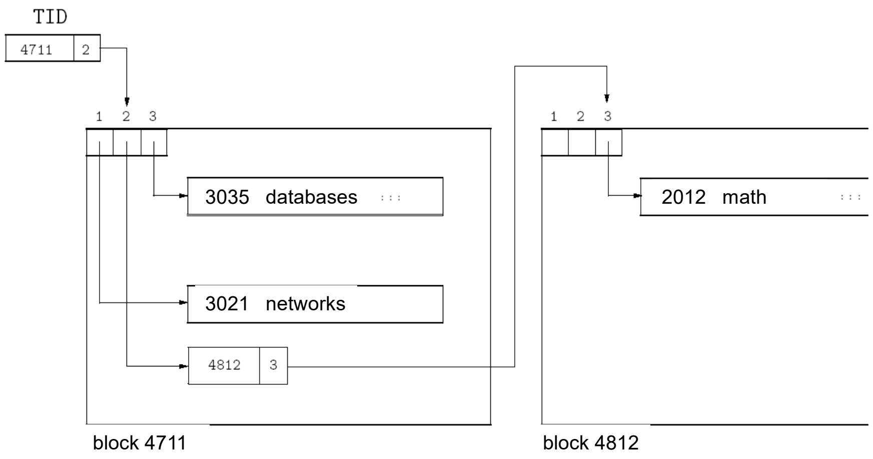
3035 databases . . .

3021 networks . . .

2012 math . . .

block 4711

Movement to Different Block



TID

4711 2

1 2 3

3035 databases . . .

3021 networks

4812 3

block 4711

1 2 3

2012 math . . .

block 4812

Options for Deletion

(a) Immediately reclaim space

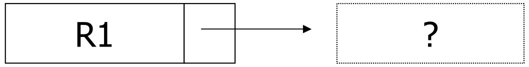
(b) Mark deleted

- Need a way to mark:
  - special characters
  - in map
- May need chain of deleted records (for re-use)

As usual many tradeoffs

- How expensive is it to move valid record to free space for immediate reclaim?
- How much space is wasted?
  - e.g., deleted records, delete fields, free space chains,...

Dangling Pointers

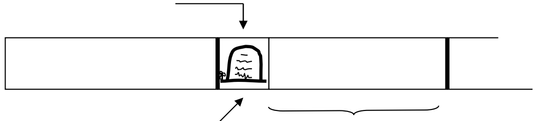


Solution: Tombstones (1)

E.g., leave “MARK” in map or old location

- Physical IDs

A block



This space
never re-used

This space can
be re-used

Solution: Tombstones (2)

E.g., Leave “MARK” in map or old location

- Logical IDs

map

ID	LOC
7788	

Never reuse
ID 7788 nor
space in map...

Pointer Swizzling

Typical DB structure:

- Data maintained by DBMS, using physical or logical addresses of perhaps 8 bytes.
- Application programs are clients with their own (conventional, virtual-memory) address spaces.

When blocks and records are copied to client's memory, DB addresses can be swizzled = translated to virtualmemory addresses.

- Allows conventional pointer following.
- Especially important in OODBMS, where pointers refer to other objects.

Swizzling Options

1. Never swizzle. Keep a translation table of DB pointers to local pointers; consult table to follow any DB pointer.

- Problem: time to follow pointers.

2. Automatic swizzling. When a block is copied to memory, replace all its DB pointers by local pointers.

- Problem: large investment if not too many pointerfollowings occur.

3. Swizzle on demand. When a block is copied to memory, do not translate pointers within the block. If we follow a pointer, translate it the first time.

- Problem: requires a bit in pointer fields for DB/local, extra decision at each pointer following.

Returning Blocks to Disk

Pointers in the returned block must be unswizzled.

Locate swizzled pointers to block (list has to be managed) and unswizzle.