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:

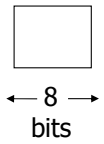
- Field represents an attribute or relationship.
- Record represents an object.
- File represents extent of a class.

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

Example:
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

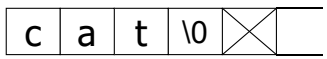
Dates

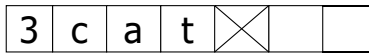
e.g.: - Integer, # days since Jan 1, 1900
- 8 characters, YYYYMMDD
(not YYMMDD!)
- 7 characters, YYYYDDD
- SQL: YYYY-MM-DD

Time

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

Strings of Characters

- Null terminated
e.g., 

- Length given
e.g., 

- Fixed length

Records

Consider fixed-length records first

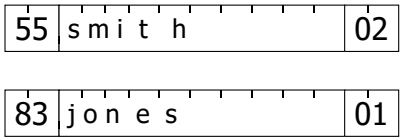
Record the consists of

- 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



Records

Record Header

Usually the fields of the record are preceded by a header

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

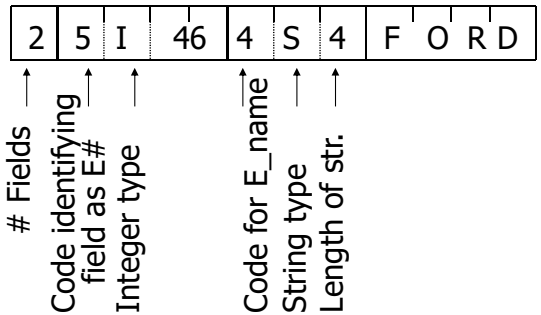
- record format (pointer to schema),
- record length,
- timestamp.

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



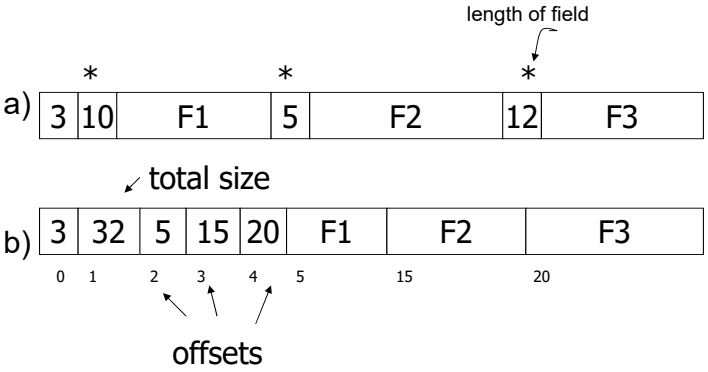
Field name codes could also be strings, i.e. TAGS

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:

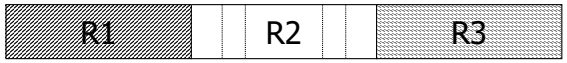
1. Block header = space for info such as:
   - Links to other blocks of a data structure.
   - Role info for this block, e.g., for which relation does the block hold tuples?
   - Directory of records in the block.
   - Block ID.
   - Timestamp.
2. Some number of records

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?

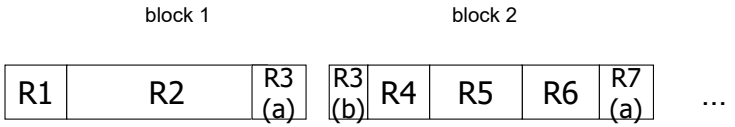
Block 

(a) no need to separate - fixed size recs.
(b) special marker
(c) give record lengths (or offsets)
- within each record
- in block header

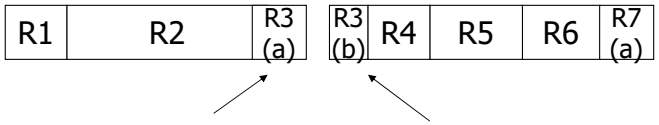
Spanned vs. Unspanned

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

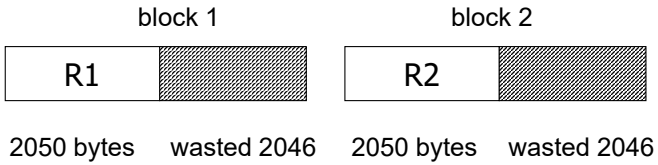
record size > block size

Example

10^6 records

each of size 2,050 bytes (fixed)

block size = 4096 bytes



And so on.....

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

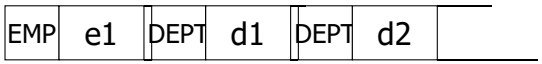
Total space $\approx 4 \times 10^9$

With 2,050-byte records and 4,096-byte blocks, only 1 record per block fits.

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

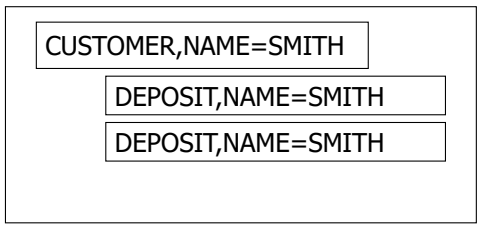
Q1: select A#, C_NAME, C_CITY, …

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

"Clustering is counter productive":
This means that creating a clustered index (physically organizing the data on disk based on a certain column) will not improve performar for this query — and may even slow it down.

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

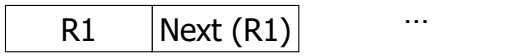
Why sequencing?

Typically to make it possible to efficiently read records in order

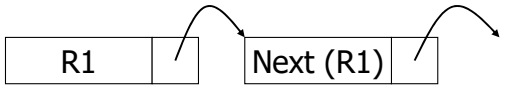
- e.g., to do a merge-join — discussed later

Sequencing Options (1)

(a) Next record physically contiguous

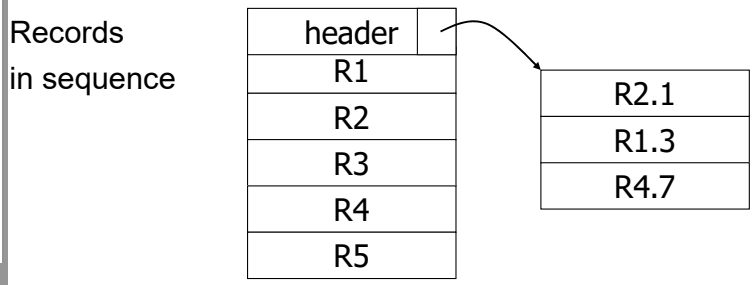


(b) Linked



Sequencing Options (2)

(c) Overflow area



Addressing

How does one refer to records?

Two approaches:

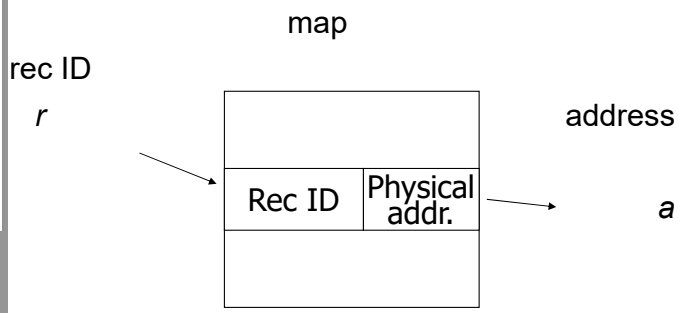
1. Physical: sequence of bytes describing location

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.

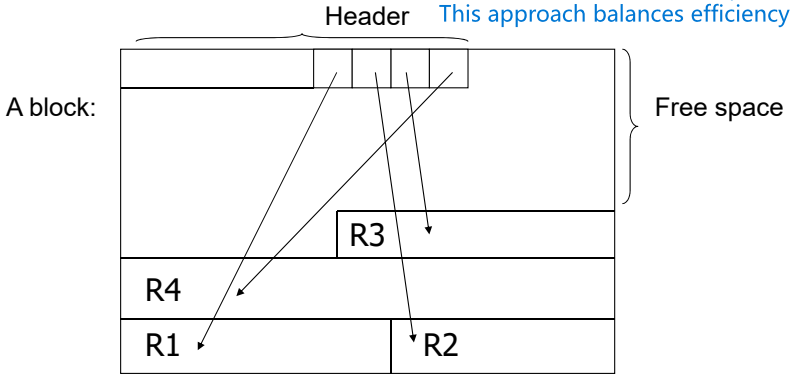
Common compromise: physical to block level, table of record offsets within blocks.

- 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

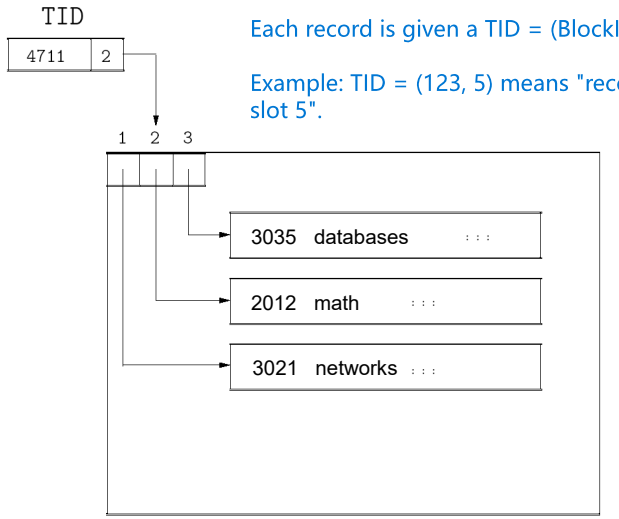
Indirection in Block

- Common Compromise in DBMS

DBMSs usually mix both approaches:
Physical addressing to the block level.
Each record is identified by its block number (fast access).
Logical addressing inside the block.
Within a block, a slot table (offset table) tells where each record s
This approach balances efficiency and flexibility.



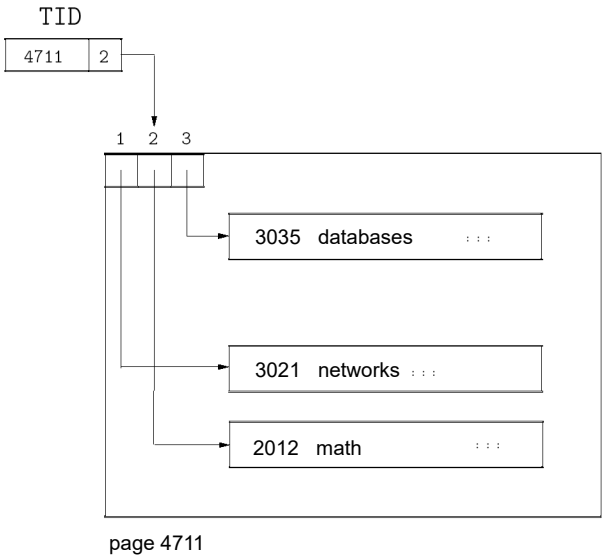
TID Example



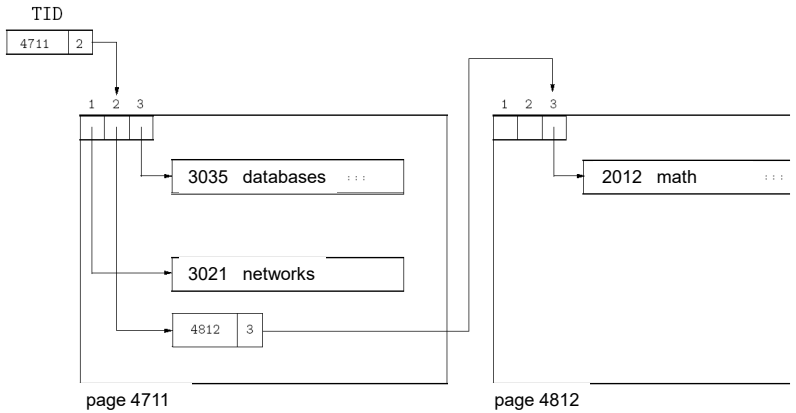
Each record is given a TID = (BlockID, SlotID).

Example: TID = (123, 5) means "record in Block 123, slot 5".

Movement Within Block



Movement to Different Block



Options for Deletion

(a) Immediately reclaim space

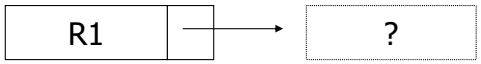
(b) Mark deleted

- 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,...

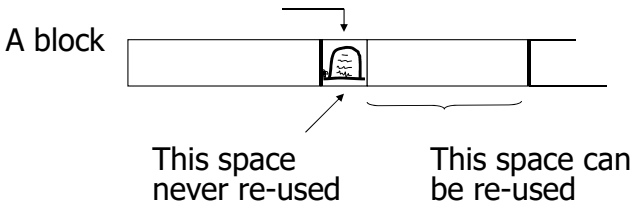
Dangling Pointers



Solution: Tombstones (1)

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

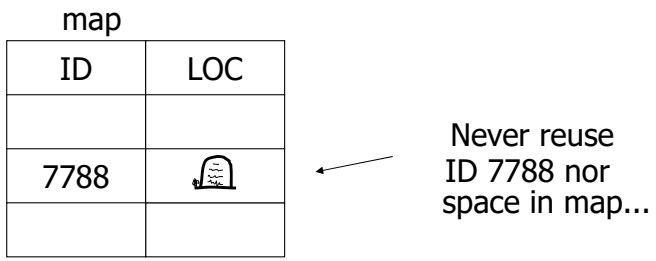
- Physical IDs



Solution: Tombstones (2)

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

- Logical IDs



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.