

CHAPTER 13



Data Storage Structures

Practice Exercises

- 13.1** Consider the deletion of record 5 from the file of Figure 13.3. Compare the relative merits of the following techniques for implementing the deletion:
- Move record 6 to the space occupied by record 5, and move record 7 to the space occupied by record 6.
 - Move record 7 to the space occupied by record 5.
 - Mark record 5 as deleted, and move no records.

Answer:

- Although moving record 6 to the space for 5 and moving record 7 to the space for 6 is the most straightforward approach, it requires moving the most records and involves the most accesses.
 - Moving record 7 to the space for 5 moves fewer records but destroys any ordering in the file.
 - Marking the space for 5 as deleted preserves ordering and moves no records, but it requires additional overhead to keep track of all of the free space in the file. This method may lead to too many “holes” in the file, which if not compacted from time to time, will affect performance because of the reduced availability of contiguous free records.
- 13.2** Show the structure of the file of Figure 13.4 after each of the following steps:
- Insert (24556, Turnamian, Finance, 98000).
 - Delete record 2.
 - Insert (34556, Thompson, Music, 67000).

Answer:

header	↑ 4			
record 0	10101	Srinivasan	Comp. Sci.	65000
record 1	24556	Turnamian	Finance	98000
record 2	15151	Mozart	Music	40000
record 3	22222	Einstein	Physics	95000
record 4				↑ 6
record 5	33456	Gold	Physics	87000
record 6				
record 7	58583	Califieri	History	62000
record 8	76543	Singh	Finance	80000
record 9	76766	Crick	Biology	72000
record 10	83821	Brandt	Comp. Sci.	92000
record 11	98345	Kim	Elec. Eng.	80000

Figure 13.101 The file after insert (24556, Turnamian, Finance, 98000).

header	↑ 2			
record 0	10101	Srinivasan	Comp. Sci.	65000
record 1	24556	Turnamian	Finance	98000
record 2				↑ 4
record 3	22222	Einstein	Physics	95000
record 4				↑ 6
record 5	33456	Gold	Physics	87000
record 6				
record 7	58583	Califieri	History	62000
record 8	76543	Singh	Finance	80000
record 9	76766	Crick	Biology	72000
record 10	83821	Brandt	Comp. Sci.	92000
record 11	98345	Kim	Elec. Eng.	80000

Figure 13.102 The file after delete record 2.

We use “↑ *i*” to denote a pointer to record “*i*”.

- See ??.
 - See ??.
 - See ??.
- Note that the free record chain could have alternatively been from the header to 4, from 4 to 2, and finally from 2 to 6.

header	↑ 4			
record 0	10101	Srinivasan	Comp. Sci.	65000
record 1	24556	Turnamian	Finance	98000
record 2	34556	Thompson	Music	67000
record 3	22222	Einstein	Physics	95000
record 4				↑ 6
record 5	33456	Gold	Physics	87000
record 6				
record 7	58583	Califieri	History	62000
record 8	76543	Singh	Finance	80000
record 9	76766	Crick	Biology	72000
record 10	83821	Brandt	Comp. Sci.	92000
record 11	98345	Kim	Elec. Eng.	80000

Figure 13.103 The file after insert (34556, Thompson, Music, 67000).

- 13.3** Consider the relations *section* and *takes*. Give an example instance of these two relations, with three sections, each of which has five students. Give a file structure of these relations that uses multitable clustering.

Answer:

The relation *section* with three tuples is as follows:

course_id	sec_id	semester	year	building	room
BIO-301	1	Summer	2010	Painter	514
CS-101	1	Fall	2009	Packard	101
CS-347	1	Fall	2009	Taylor	3128

The relation *takes* with five students for each section is as follows:

See ??.

See ??.

The multitable clustering for the above two instances can be taken as:

- 13.4** Consider the bitmap representation of the free-space map, where for each block in the file, two bits are maintained in the bitmap. If the block is between 0 and 30 percent full the bits are 00, between 30 and 60 percent the bits are 01, between 60 and 90 percent the bits are 10, and above 90 percent the bits are 11. Such bitmaps can be kept in memory even for quite large files.

- Outline two benefits and one drawback to using two bits for a block, instead of one byte as described earlier in this chapter.

ID	course_id	sec_id	semester	year	grade
00128	CS-101	1	Fall	2009	A
00128	CS-347	1	Fall	2009	A-
12345	CS-347	1	Fall	2009	A
12345	CS-101	1	Fall	2009	C
17968	BIO-301	1	Summer	2010	null
23856	CS-347	1	Fall	2009	A
45678	CS-101	1	Fall	2009	F
54321	CS-101	1	Fall	2009	A-
54321	CS-347	1	Fall	2009	A
59762	BIO-301	1	Summer	2010	null
76543	CS-101	1	Fall	2009	A
76543	CS-347	1	Fall	2009	A
78546	BIO-301	1	Summer	2010	null
89729	BIO-301	1	Summer	2010	null
98988	BIO-301	1	Summer	2010	null

Figure 13.104 The relation *takes* with five students for each section.

- b. Describe how to keep the bitmap up to date on record insertions and deletions.
- c. Outline the benefit of the bitmap technique over free lists in searching for free space and in updating free space information.

Answer:

- a. The space used is less with 2 bits, and the number of times the free-space map needs to be updated decreases significantly, since many inserts/deletes do not result in any change in the free-space map. However, we have only an approximate idea of the free space available, which could lead both to wasted space and/or to increased search cost for finding free space for a record.
- b. Every time a record is inserted/deleted, check if the usage of the block has changed levels. In that case, update the corresponding bits. Note that we don't need to access the bitmaps at all unless the usage crosses a boundary, so in most of the cases there is no overhead.
- c. When free space for a large record or a set of records is sought, then multiple free list entries may have to be scanned before a proper-sized one is found, so overheads are much higher. With bitmaps, one page of bitmap can store free info for many pages, so I/O spent for finding free space is minimal. Similarly, when a whole block or a large part of it is

BIO-301	1	Summer	2010	Painter	5
17968	BIO-301	1	Summer	2010	n
59762	BIO-301	1	Summer	2010	n
78546	BIO-301	1	Summer	2010	n
89729	BIO-301	1	Summer	2010	n
98988	BIO-301	1	Summer	2010	n
CS-101	1	Fall	2009	Packard	1
00128	CS-101	1	Fall	2009	A
12345	CS-101	1	Fall	2009	C
45678	CS-101	1	Fall	2009	F
54321	CS-101	1	Fall	2009	A
76543	CS-101	1	Fall	2009	A
CS-347	1	Fall	2009	Taylor	3
00128	CS-347	1	Fall	2009	A
12345	CS-347	1	Fall	2009	A
23856	CS-347	1	Fall	2009	A
54321	CS-347	1	Fall	2009	A
76543	CS-347	1	Fall	2009	A

Figure 13.105 The multitable clustering for the above two instances can be taken as:

deleted, bitmap technique is more convenient for updating free space information.

- 13.5** It is important to be able to quickly find out if a block is present in the buffer, and if so where in the buffer it resides. Given that database buffer sizes are very large, what (in-memory) data structure would you use for this task?

Answer:

Hash table is the common option for large database buffers. The hash function helps in locating the appropriate bucket on which linear search is performed.

- 13.6** Suppose your university has a very large number of *takes* records, accumulated over many years. Explain how table partitioning can be done on the *takes* relation, and what benefits it could offer. Explain also one potential drawback of the technique.

Answer:

The table can be partitioned on (year, semester). Old *takes* records that are no longer accessed frequently can be stored on magnetic disk, while newer records can be stored on SSD. Queries that specify a year can be answered without reading records for other years.

A drawback is that queries that fetch records corresponding to multiple years will have a higher overhead, since the records may be partitioned across different relations and disk blocks.

- 13.7** Give an example of a relational-algebra expression and a query-processing strategy in each of the following situations:
- MRU is preferable to LRU.
 - LRU is preferable to MRU.

Answer:

- MRU is preferable to LRU where $R_1 \bowtie R_2$ is computed by using a nested-loop processing strategy where each tuple in R_2 must be compared to each block in R_1 . After the first tuple of R_2 is processed, the next needed block is the first one in R_1 . However, since it is the least recently used, the LRU buffer management strategy would replace that block if a new block was needed by the system.
- LRU is preferable to MRU where $R_1 \bowtie R_2$ is computed by sorting the relations by join values and then comparing the values by proceeding through the relations. Due to duplicate join values, it may be necessary to “back up” in one of the relations. This “backing up” could cross a block boundary into the most recently used block, which would have been replaced by a system using MRU buffer management, if a new block was needed.

Under MRU, some unused blocks may remain in memory forever. In practice, MRU can be used only in special situations like that of the nested-loop strategy discussed in Exercise Section 13.8a.

- 13.8** PostgreSQL normally uses a small buffer, leaving it to the operating system buffer manager to manage the rest of main memory available for file system buffering. Explain (a) what is the benefit of this approach, and (b) one key limitation of this approach.

Answer:

The database system does not know what are the memory demands from other processes. By using a small buffer, PostgreSQL ensures that it does not grab too much of main memory. But at the same time, even if a block is evicted from buffer, if the file system buffer manager has enough memory allocated to it, the evicted page is likely to still be cached in the file system buffer. Thus, a database buffer miss is often not very expensive since the block is still in the file system buffer.

The drawback of this approach is that the database system may not be able to control the file system buffer replacement policy. Thus, the operating system may make suboptimal decisions on what to evict from the file system buffer.

