Fakultas Informatika
School of Computing
Telkom University

Database System

03 | Indexing

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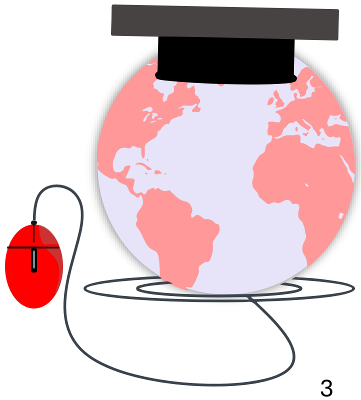
GOALS OF MEETING

1. Students knows the basic concepts of indexing
2. Students understand how to organize B+-Tree Index Files
3. Students can create indexes on the DBMS to speed up searching performance

OUTLINES

- Basic Concepts
- Ordered Indices
- B+-Tree Index Files
- Creation of Indices



BASIC CONCEPTS

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- Indexing mechanisms used to speed up access to desired data.
  - E.g., author catalog in library
- **Search Key** - attribute to set of attributes used to look up records in a file.
- An **index file** consists of records (called **index entries**) of the form:

search-key	pointer

- Index files are typically much smaller than the original file
- Two basic kinds of indices:
  - **Ordered indices:** search keys are stored in sorted order
  - **Hash indices:** search keys are distributed uniformly across "buckets" using a "hash function".

ORDERED INDICES

- In an **ordered index,** index entries are stored sorted on the search key value.
- **Clustering index:** in a sequentially ordered file, the index whose search key specifies the sequential order of the file.
  - Also called **primary index**
  - The search key of a primary index is usually but not necessarily the primary key.
- **Secondary index**: an index whose search key specifies an order different from the sequential order of the file. Also called **nonclustering index.**
- **Index-sequential file:** sequential file ordered on a search key, with a clustering index on the search key.

DENSE INDEX FILES

- **Dense index** — Index record appears for every search-key value in the file.
- E.g. index on *ID* attribute of *instructor* relation

10101	
12121	
15151	
22222	
32343	
33456	
45565	
58583	
76543	
76766	
83821	
98345	

10101	Srinivasan	Comp. Sci.	65000	
12121	Wu	Finance	90000	
15151	Mozart	Music	40000	
22222	Einstein	Physics	95000	
32343	El Said	History	60000	
33456	Gold	Physics	87000	
45565	Katz	Comp. Sci.	75000	
58583	Califieri	History	62000	
76543	Singh	Finance	80000	
76766	Crick	Biology	72000	
83821	Brandt	Comp. Sci.	92000	
98345	Kim	Elec. Eng.	80000	

DENSE INDEX FILES (CONT.)

- Dense index on *dept_name*, with *instructor* file sorted on *dept_name*

Biology	
Comp. Sci.	
Elec. Eng.	
Finance	
History	
Music	
Physics	

76766	Crick	Biology	72000	
10101	Srinivasan	Comp. Sci.	65000	
45565	Katz	Comp. Sci.	75000	
83821	Brandt	Comp. Sci.	92000	
98345	Kim	Elec. Eng.	80000	
12121	Wu	Finance	90000	
76543	Singh	Finance	80000	
32343	El Said	History	60000	
58583	Califieri	History	62000	
15151	Mozart	Music	40000	
22222	Einstein	Physics	95000	
33465	Gold	Physics	87000	

SPARSE INDEX FILES

- **Sparse Index**: contains index records for only some search-key values.
  - Applicable when records are sequentially ordered on search-key

10101	
32343	
76766	

10101	Srinivasan	Comp. Sci.	65000	
12121	Wu	Finance	90000	
15151	Mozart	Music	40000	
22222	Einstein	Physics	95000	
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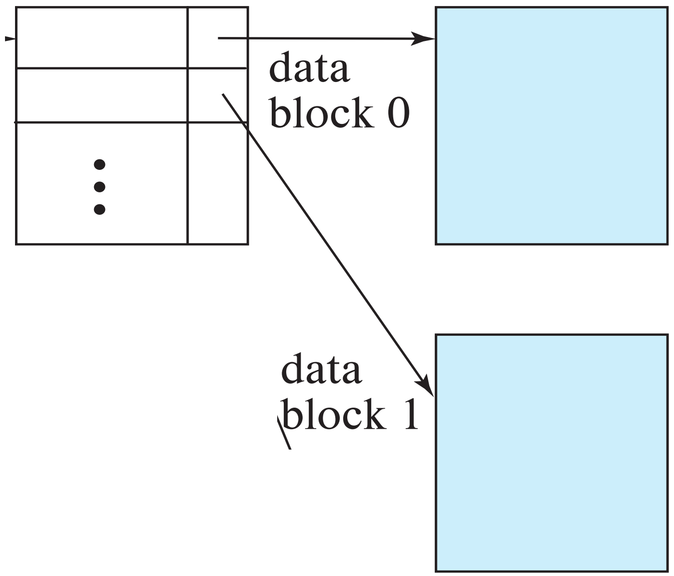
- To locate a record with search-key value *K* we:
  - Find index record with largest search-key value < *K*
  - Search file sequentially starting at the record to which the index record points

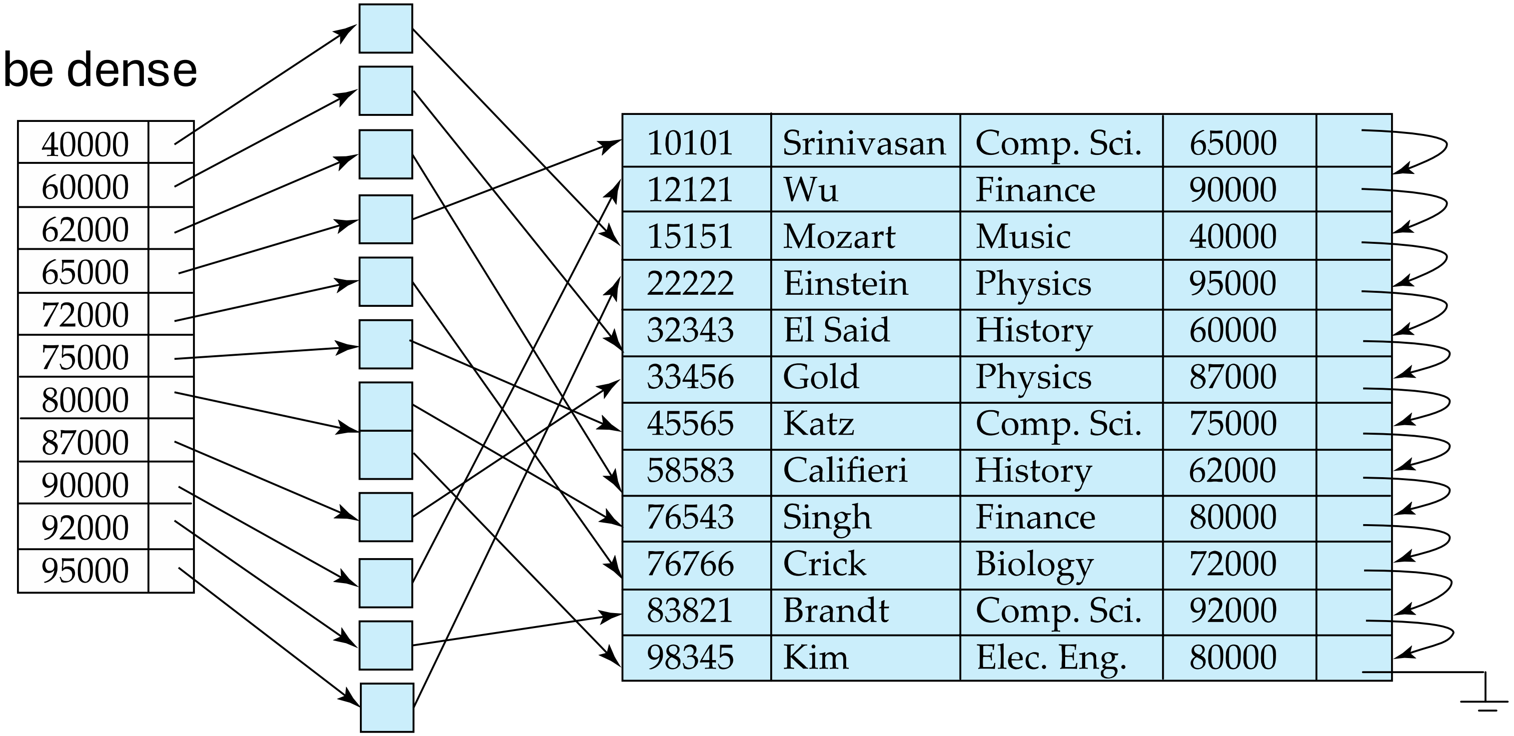
SPARSE INDEX FILES (CONT.)

- Compared to dense indices:
  - Less space and less maintenance overhead for insertions and deletions.
  - Generally slower than dense index for locating records.
- **Good tradeoff**:
  - for clustered index: sparse index with an index entry for every block in file, corresponding to least search-key value in the block.
  - For unclustered index: sparse index on top of dense index (multilevel index)



SECONDARY INDICES EXAMPLE

- Secondary index on salary field of instructor
- Index record points to a bucket that contains pointers to all the actual records with that particular search-key value.
- Secondary indices have to be dense



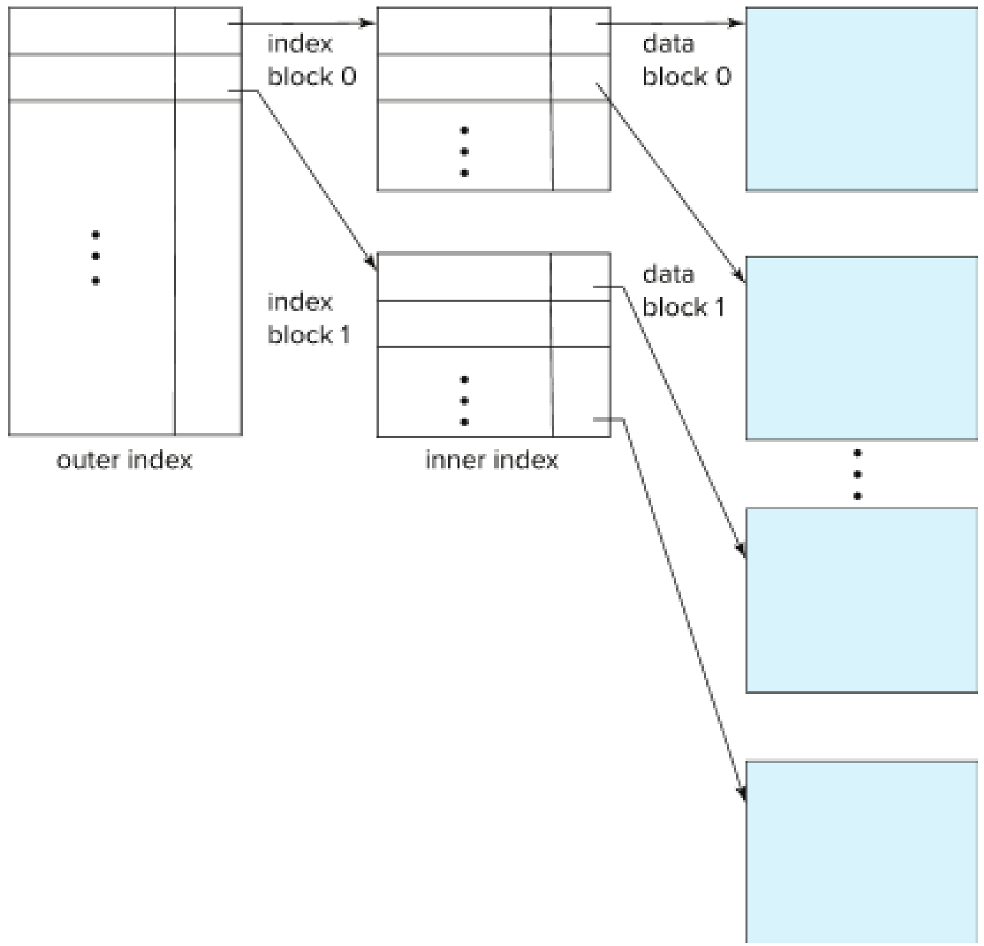
CLUSTERING VS NONCLUSTERING INDICES

- Indices offer substantial benefits when searching for records.
- BUT: indices imposes overhead on database modification
  - when a record is inserted or deleted, every index on the relation must be updated
  - When a record is updated, any index on an updated attribute must be updated
- Sequential scan using clustering index is efficient, but a sequential scan using a secondary (nonclustering) index is expensive on magnetic disk
  - Each record access may fetch a new block from disk
  - Each block fetch on magnetic disk requires about 5 to 10 milliseconds

MULTILEVEL INDEX

- If index does not fit in memory, access becomes expensive.
- Solution: treat index kept on disk as a sequential file and construct a sparse index on it.
  - outer index – a sparse index of the basic index
  - inner index – the basic index file
- If even outer index is too large to fit in main memory, yet another level of index can be created, and so on.
- Indices at all levels must be updated on insertion or deletion from the file.

MULTILEVEL INDEX (CONT.)

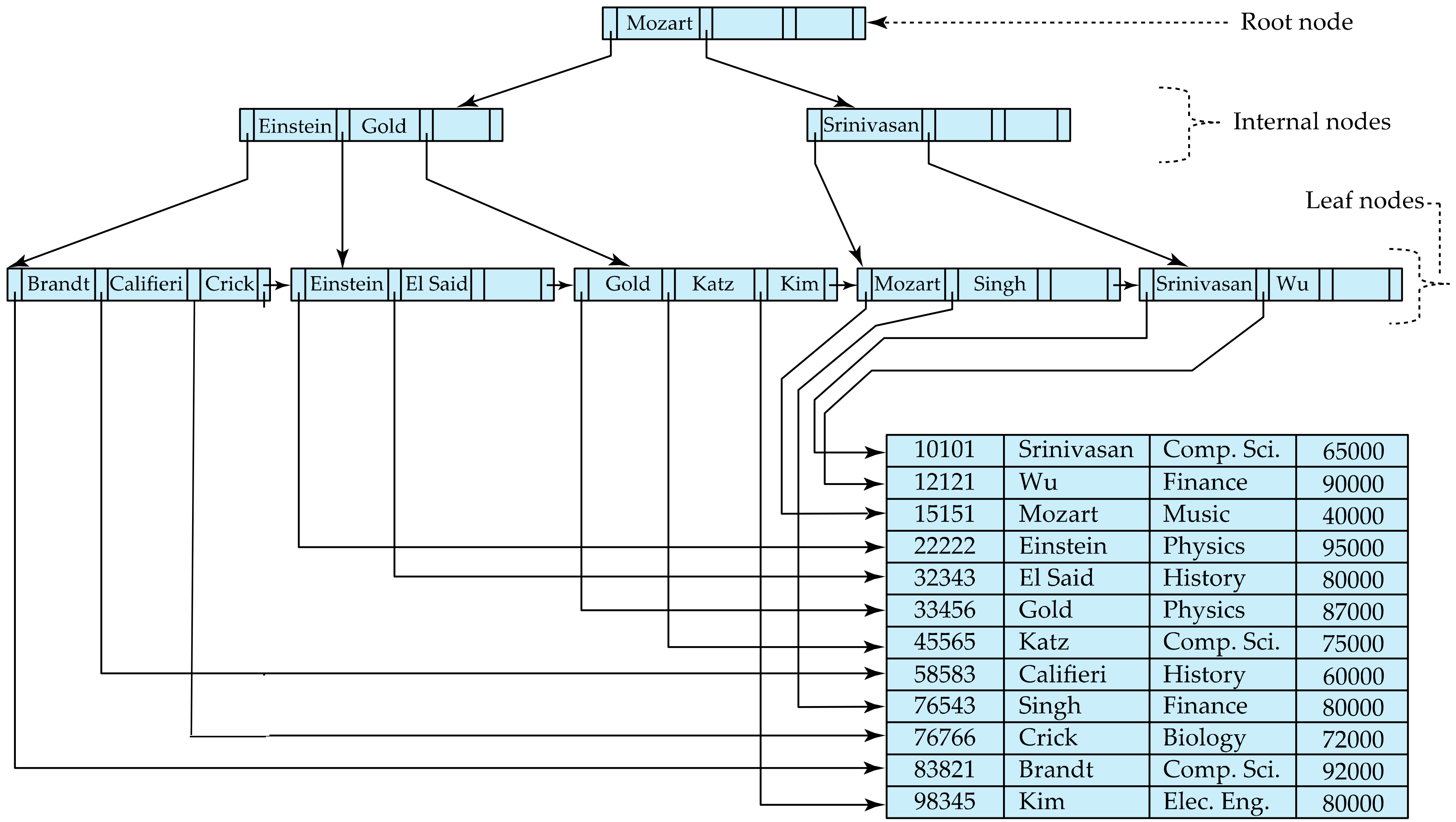


B+-TREE INDEX FILES

B⁺-TREE INDEX FILES

- Disadvantage of indexed-sequential files
  - Performance degrades as file grows, since many overflow blocks get created.
  - Periodic reorganization of entire file is required.
- Advantage of B^+-tree index files:
  - Automatically reorganizes itself with small, local, changes, in the face of insertions and deletions.
  - Reorganization of entire file is not required to maintain performance.
- (Minor) disadvantage of B^+-trees:
  - Extra insertion and deletion overhead, space overhead.
- Advantages of B^+-trees outweigh disadvantages
  - B^+-trees are used extensively

EXAMPLE OF B^+-TREE



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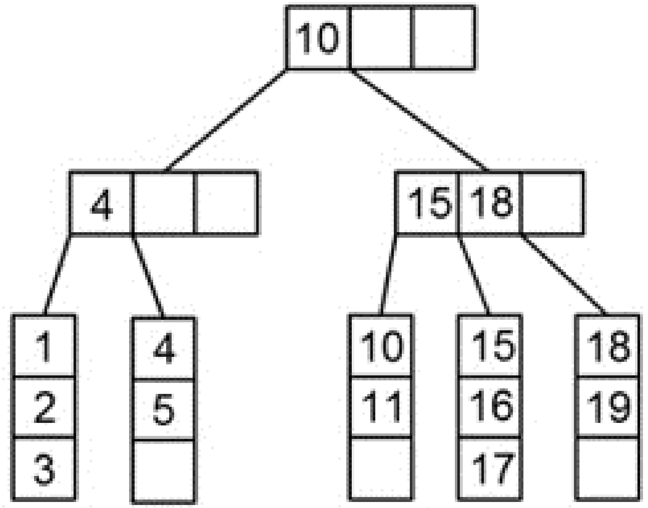
B+TREE BASIC



Source : https://youtu.be/49P_GDeMDRo

B+TREE INSERTION

Source : https://youtu.be/h6Mw7_S4ai0

B+TREE DELETION

Source : https://youtu.be/QrbaQDSuxlM

CREATION OF INDICES

CREATION OF INDICES

- Example

  create index *takes_pk* **on** *takes* (*ID,course_ID, year, semester, section*)

  drop index *takes_pk*

- Most database systems allow specification of type of index, and clustering.
- Indices on primary key created automatically by all databases
  - Why?
- Some database also create indices on foreign key attributes
  - Why might such an index be useful for this query:
    - $takes \bowtie \sigma_{name='Shankar'}(student)$
- Indices can greatly speed up lookups, but impose cost on updates
  - Index tuning assistants/wizards supported on several databases to help choose indices, based on query and update workload

INDEX DEFINITION IN SQL

- Create an index:

  create index <index-name> **on** <relation-name>(<attribute-list>)

  E.g.,: **create index** *b-index* **on** *branch(branch_name)*

- Use **create unique index** to indirectly specify and enforce the condition that the search key is a candidate key is a candidate key.
  - Not really required if SQL **unique** integrity constraint is supported
- To drop an index:

  drop index <index-name>

- Most database systems allow specification of type of index, and clustering.

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REFERENCES

Silberschatz, Korth, and Sudarshan. *Database System Concepts* – 7th Edition. McGraw-Hill. 2019.

Slides adapted from Database System Concepts Slide.

Source: https://www.db-book.com/db7/slides-dir/index.html


ANY
QUESTIONS?