INDEXING

CS 564- Fall 2015

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FILE ORGANIZATIONS

- So far we have seen heap files
  - unordered data
  - fast for scanning all records in a file
  - fast for retrieving by record id (rid)

- Do we need alternative organizations of a file?

MOTIVATION

- Consider the following SQL query:

```
SELECT *
FROM Sales
WHERE Sales.date = “02-10-2015”
```

- What is the execution like for a heap file?

ALTERNATIVE FILE ORGANIZATIONS

- We can speed up query execution by better organizing the data in a file!
- There are many alternatives:
  - Sorted files
  - Indexes
    - B+ tree
    - Hash index

INDEXES

INDEXES

- Indexes: data structures that organize records via trees or hashing
  - they speed up searches for a subset of records, based on values in certain (search key) fields
  - any subset of the fields of a relation can be the search key
  - the search key is not the same as key!
- An index contains a collection of data entries (each entry with enough info to locate the records)

HASH INDEX

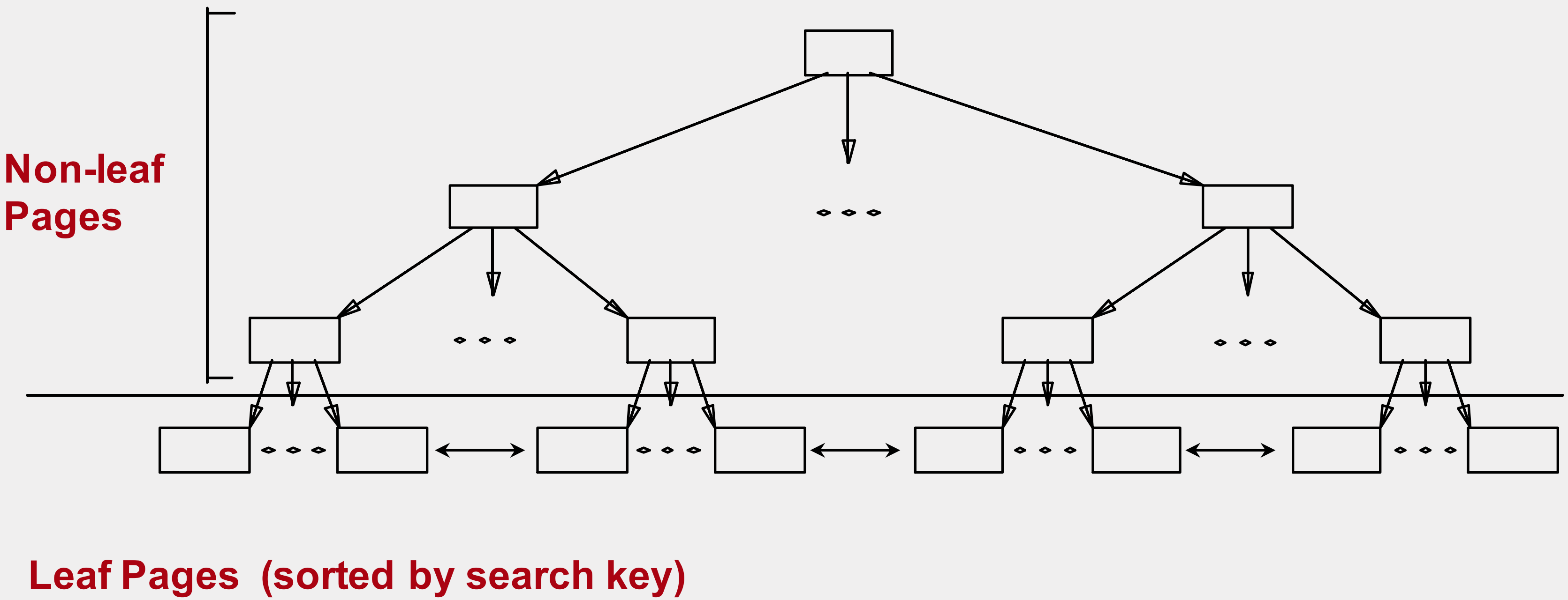
- A hash index is a collection of buckets
  - bucket = primary page plus overflow pages
  - buckets contain data entries
- Uses a hash function **h**
  - **h**(r) = bucket in which (data entry for) record r belongs
- Good for equality search
- Not so good for range search (use tree indexes instead)

Hash Index Example

`Sales (sid, product, date, price)`

On the blackboard!

B+ Tree Index



- Leaf pages contain data entries, and are chained (prev & next)
- Non-leaf pages have data entries

Data Entries

- The actual data may not be in the same file as the index!
- In a data entry with search key **k** we can store:
  1. the record with key value **k**
  2. <**k**, rid of record with search key value **k**>
  3. <**k**, list of rids of records with search key **k**>
- The choice of alternative for data entries is orthogonal to the indexing technique

ALTERNATIVES FOR DATA ENTRIES

Alternative #1:

- index structure is a file organization for records
- at most one index on a given collection of data records should use #1 (why?)
- if data records are very large, the number of pages containing data entries is high (slower search)

ALTERNATIVES FOR DATA ENTRIES

Alternatives #2 and #3:

- Data entries are typically much smaller than data records. So, better than #1 with large data records, especially if search keys are small
- #3 is more compact than #2, but leads to variable sized data entries even if search keys are of fixed length

More on Indexes

- A file can have several indexes!
- Index classification:
  - clustered **vs** unclustered
  - primary **vs** secondary

PRIMARY VS SECONDARY

- If the search key contains the primary key, it is called a primary index
- Any other index is called a secondary index
- If the search key contains a candidate key, it is called a unique index
    - returns no duplicates

EXAMPLE

`Sales (sid, product, date, price)`

- An index on (sid) is a primary and unique index
- An index on (date) is a secondary, but not unique, index

Clustered Indexes

- If the order of records is the same as, or `close to', the order of data entries, it is a clustered index
  - alternative #1 implies clustered; in practice, clustered also implies #1
  - a file can be clustered on at most one search key
  - the cost of retrieving data records through index varies greatly based on whether index is clustered or not (why?)

EXAMPLE

`Sales (sid, product, date, price)`

On blackboard!

INDEXES IN PRACTICE

Choosing Indexes

- What indexes should we create?
  - Which relations should have indexes?
  - What field(s) should be the search key?
  - Should we build several indexes?
- For each index, what kind of an index should it be?
  - clustered?
  - hash/tree?

Choosing Indexes

- Consider the best plan using the current indexes, and see if a better plan is possible with an additional index. If so, create it.
  - One must understand how a DBMS evaluates queries and creates query evaluation plans
  - Important trade-offs:
    - queries go faster, updates are slower
    - disk space required

Choosing Indexes

- Attributes in **WHERE** clause are candidates for index keys
  - Exact match condition suggests hash index
  - Indexes also speed up joins (later in class)
  - Range query suggests tree index

- Multi-attribute search keys should be considered when a WHERE clause contains several conditions
  - Order of attributes is important for range queries
  - Such indexes can enable index-only strategies for queries

INDEXES IN SQL

```
CREATE INDEX index_name
ON table_name (column_name);
```

- Example:

```
CREATE INDEX index1
ON Sales (price);
```

Indexes in SQL

```sql
CREATE UNIQUE INDEX index2
ON Sales (sid);
```

- A unique index does not allow any duplicate values to be inserted into the table
- Can be used to check integrity constaints!

Composite Indexes

- Composite Search Keys: search on a combination of fields (e.g. <date, price>)
  - Equality query: Every field value is equal to a constant value
    - date="02-20-2015" and price =75
  - Range query: Some field value is not a constant
    - date="02-20-2015"
    - date="02-20-2015" and price > 40

COMPOSITE INDEXES IN SQL

```
CREATE INDEX index3
ON Sales (date, price);
```

Composite Keys

- Composite indexes are larger and more expensive to update
- Can be used if we have multiple selection conditions