Indexes and Indexing

Searching

Telephone book

Phone number of "Samuel Clemens"
Address of person with phone number "123-456-7890"

Other examples

Searching on the web
Searching for a topic in a book
Using codebooks

Sorting and Searching

Searching on an unordered domain of n items: *linear search*

- takes n/2 steps on average
- n steps worst case

Searching on an ordered domain of n items: *binary search*

- $O(\log_2 n)$ worst case

Order

Ordered data can be searched fast

Establishing order is expensive, O(n log n)

Maintaining order
- requires dynamic data structures (for deletions and insertions) **and**
- is expensive, O(log n), or O(1) amortized (with more difficult algorithms)

Conclusion: order is important, but expensive

Order is important?

```
SELECT *
FROM lg_student
WHERE SID = 123456;
```

```
SELECT *
FROM lg_student
WHERE SSN = 272906957;
```

- 1 million entries in database
- SID is indexed, SSN is not
- queries refer to same student

Creating Index

```
CREATE INDEX SSNIndex
ON lg_student(SSN);

SELECT *
FROM lg_student
WHERE SSN = 272906957;

DROP INDEX SSNIndex;
```

Also try with random SSN

Creating Index, Multiple Attributes

```
CREATE INDEX stprof
ON lg_student(started, program);

SELECT count(*)
FROM lg_student
WHERE started = 2005;

SELECT count(*)
FROM lg_student
WHERE program = 'COMP-SCI';
```

- Compare with/without index
- Compare execution plans

Indexes speeding Joins

```
SELECT count(*)
FROM lg_student, lg_contact
WHERE SID = StudentID;
```

investigate execution plans

vs

```
SELECT count(*)
FROM lg_student, lg_contact
WHERE SSN = StudentSSN;
```

Also

```
SELECT count(*)
FROM lg_student, lg_contact
WHERE SSN = StudentSSN AND
StudentSSN = 14161180;
```

Indexes

Two basic types of indexes:

- Ordered Indices (based on order)
- Hash Indices (based on hashing)

Record Storage

Memory:
- Volatile: cache (random access), flash memory
- Nonvolatile: discs, tapes (sequential access)

Discs
- Bit/byte
- Optical Juke Box/Disc/track/block
- pages (typically 4Kb)

Records
- Variable-lengths
- Optional or repeating fields
- Mixed records

Files

Unordered (heap files)
Records are saved sequentially on disk, block after block

Ordered (sorted files)
Records are saved in order (ordered by some *ordering* field)

Hashed files
Records are saved at a location based on a hashing function; conflicts are resolved using several different techniques

Index

Access structure to records to facilitate locating a record.

Indexes are created for particular fields in a record, usually a single field (e.g. Name in telephone book)

Indexes can have multiple levels (e.g. dictionary)

Single-Level Ordered Indexes

Example: index at the end of a book

Types	Ordering Field	Nonordering field
Key field	Primary index	Secondary index (key)
Nonkey field	Clustering index	Secondary index (nonkey)

Examples: find address given phone number in telephone book
find phone number given name in telephone book
find topic in a book
find info in a TV schedule

Primary Indexes

Index for ordering keyfield.
- File is physically ordered by field
- Values are unique (since it is a key)

Primary index is a file of records consisting of two parts of fixed length:
value of key field
pointer to disk block containing record with that value

Key is called **primary key** (not the same as p.k. in relational model), a record in the index file is called **index entry**.

Problems

Dynamic changes
insertion of a record
deletion of a record
modification of a record (new record might be longer)

Solutions:
Unordered overflow file
List of overflow records for each block
Deletion markers

Periodical file reorganization is necessary

Clustering Index

Index for ordering field which is not a key

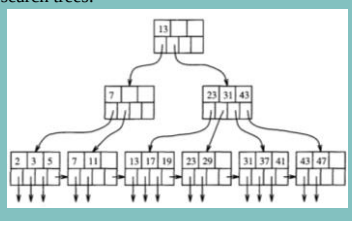
- File is physically ordered by field
- Values are not unique
- Only distinct values are indexed

Same issues as with primary index

Primary/Clustering Implementation?

Need dynamic data structures for maintaining indexes based on search trees:

- B-Tree
- B^+-Tree



Hash Indexes

A hash function maps a large set (the set of potential records) to a small set (the storage locations) without causing too many conflicts.

Use hash function to find a location to store the index information of a record.

Tuning

- By default, key fields are indexed
- Deciding which fields to index should be based on statistical analysis of frequent queries
- need to consider SELECT as well as INSERT, UPDATE and DELETE

analyze (see 8.4.3)

```
SELECT *
FROM lg_contact
WHERE StudentID = 123;
```

```
SELECT *
FROM lg_contact
WHERE telnr = 131313131;
```

```
INSERT INTO lg_contact
```