HASH INDEXES

CS 564- Spring 2018

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WHAT IS THIS LECTURE ABOUT?

Hash indexes

- Static Hashing
  - what is the I/O cost?
  - problems with static hashing
- Extendible Hashing
  - insertion
  - deletion

HOW TO EVALUATE AN INDEX?

- What access types does it support?
  - *e.g.* equalitiy search, range search, etc.
- Time to access a record
- Time to insert a record
- Time to delete a record
- How much space does it use?

HASH INDEXES

- efficient for equality search
- not appropriate for range search

- Types of hash indexes:
  - static hashing
  - extendible (dynamic) hashing

STATIC HASHING

- A **hash index** is a collection of *buckets*
  - bucket = primary page + overflow pages
  - each bucket contains one or more data entries
- To find the bucket for each record, we use a hash function $\boldsymbol{h}$ applied on the search key k
  - $\boldsymbol{N}$ = number of buckets
  - $\boldsymbol{h}(k) \bmod \boldsymbol{N}$ = bucket in which the data entry belongs
- Records with different search key may belong in the same bucket

STATIC HASHING: EXAMPLE

`Person(name,zipcode,phone)`

- *search key*: zipcode
- *hash function **h***: last 2 digits

- 4 buckets
- each bucket has 2 data entries (full record)

primary pages

overflow pages

bucket 0
(John, 534**00**, 23218564)
(Alice, 547**68**, 60743111)
→ (Anna, 536**32**, 23209964)

bucket 1
(Paris, 534**09**, 23200564)

bucket 2

bucket 3
(Maria, 344**11**, 29010533)

OPERATIONS ON HASH INDEXES

Equality search (*search-key = value*)

- apply the hash function on the search key to locate the appropriate bucket
- search through the primary page (plus overflow pages) to find the record(s)

I/O cost = 1 + #overflow pages

OPERATIONS ON HASH INDEXES

- **Deletion**
  - find the appropriate bucket, delete the record
- **Insertion**
  - find the appropriate bucket, insert the record
  - if there is no space, create a new overflow page

HASH FUNCTIONS

- An *ideal* hash function must be uniform: each bucket is assigned the same number of key values
- A *bad* hash function maps all search key values to the same bucket
- Examples of good hash functions:
  - $\boldsymbol{h}(k) = a * k + b$, where a and b are constants
  - a random function

BUCKET OVERFLOW

- Bucket *overflow* can occur because of
  - insufficient number of buckets
  - *skew* in distribution of records
    - many records have the same search-key value
    - the hash function results in a non-uniform distribution of key values

- Bucket overflow is handled using *overflow buckets*

PROBLEMS OF STATIC HASHING

- In static hashing, there is a **fixed** number of buckets in the index
- Issues with this:
  - if the database grows, the number of buckets will be too small: long overflow chains degrade performance
  - if the database shrinks, space is wasted
  - reorganizing the index is expensive and can block query execution

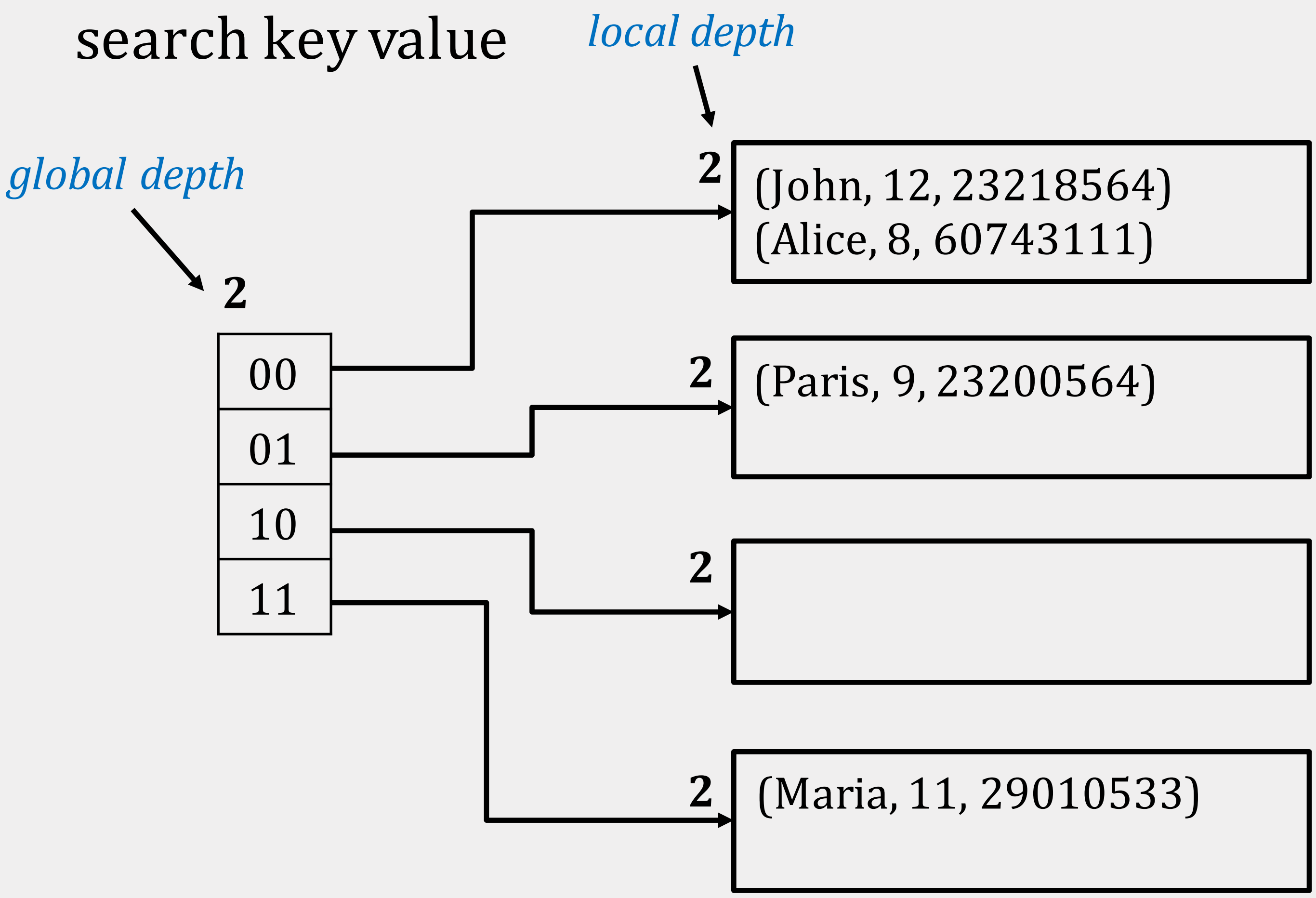
EXTENDIBLE HASHING

Extendible Hashing

- **Extendible hashing** is a type of *dynamic* hashing
- It keeps a directory of pointers to buckets
- On overflow, it reorganizes the index by doubling the directory (and not the number of buckets)

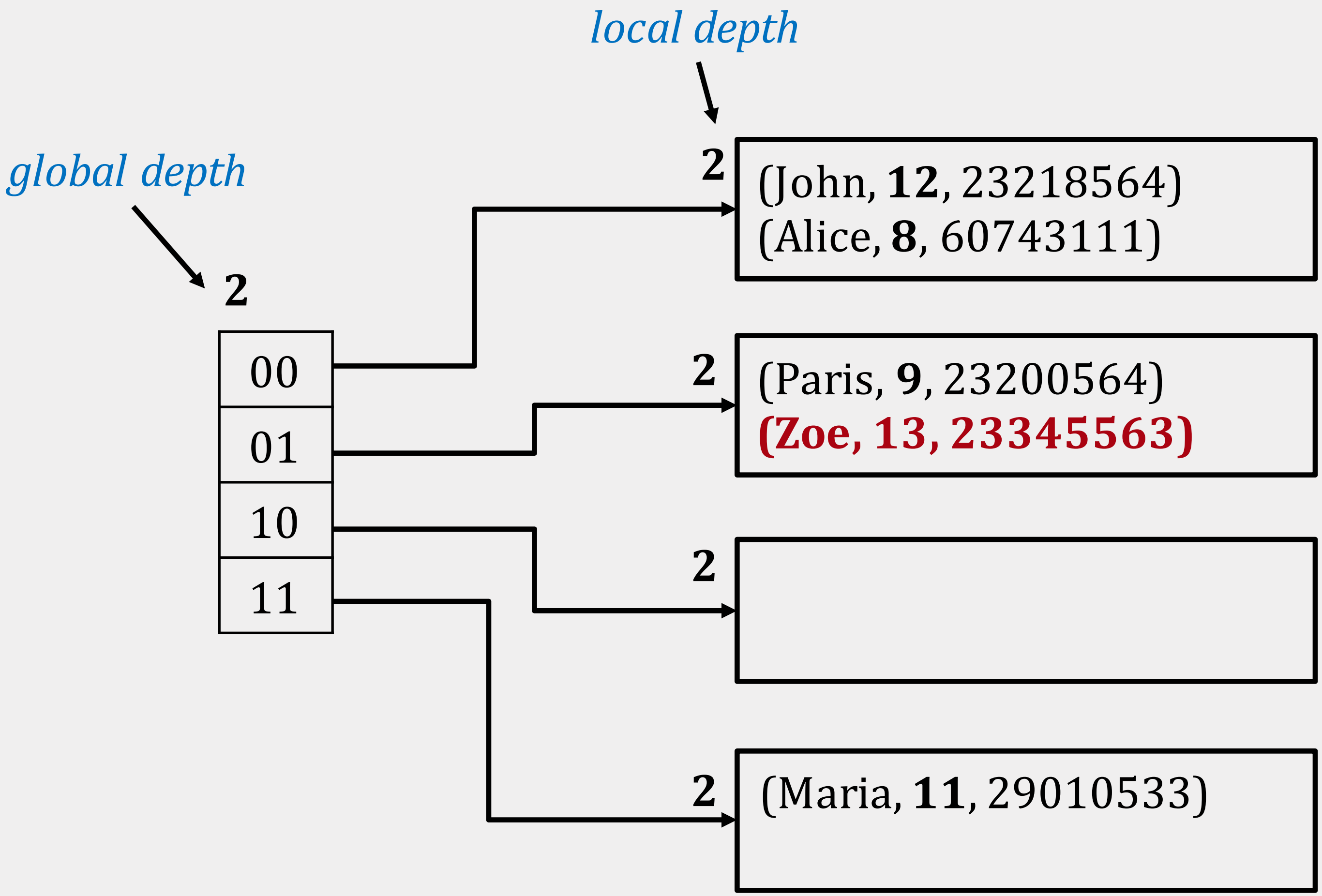
EXTENDIBLE HASHING

To search, use the last **2** digits of the **binary** form of the search key value



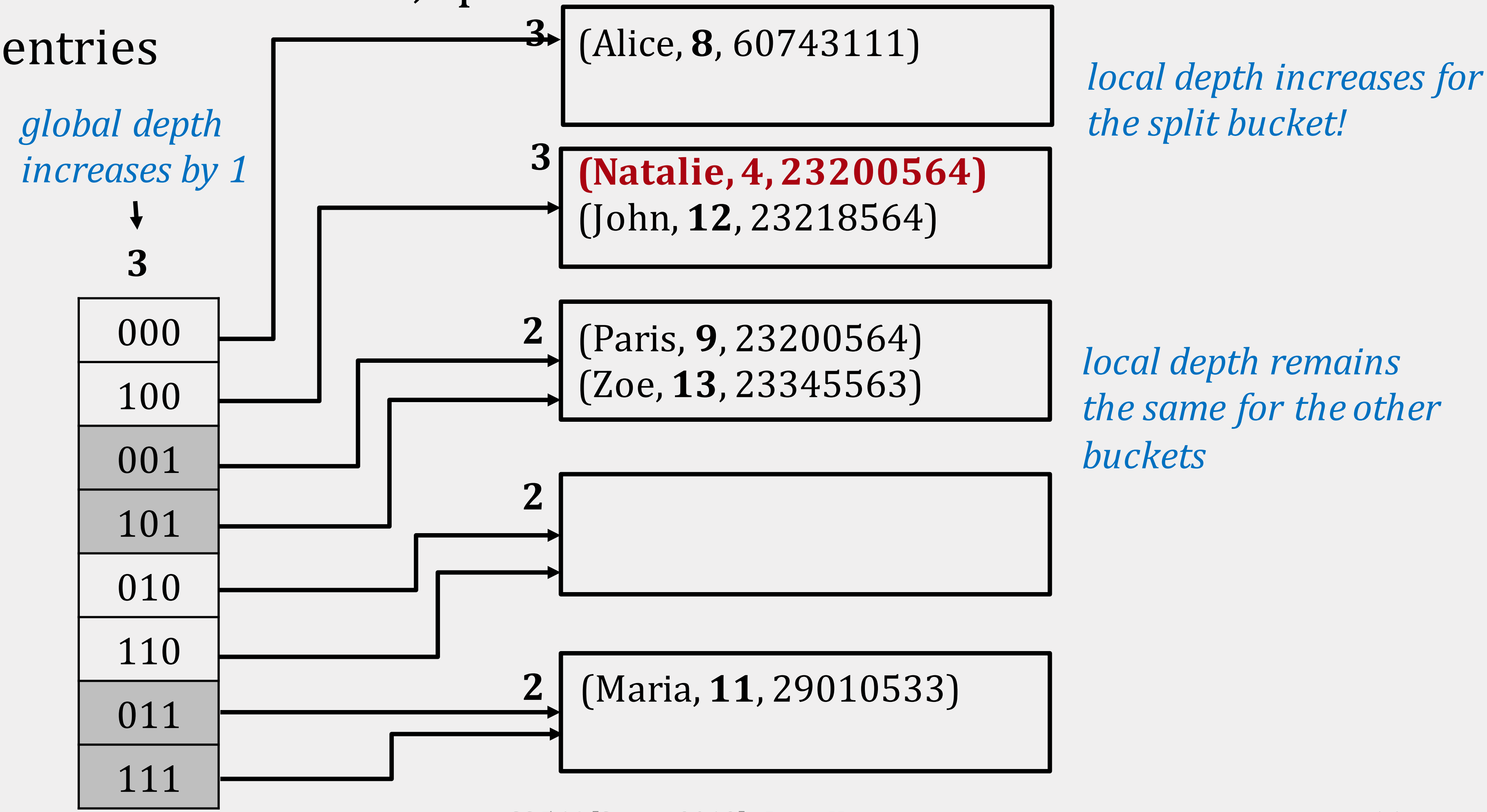
EXTENDIBLE HASHING: INSERT

If there is space in the bucket, simply add the record



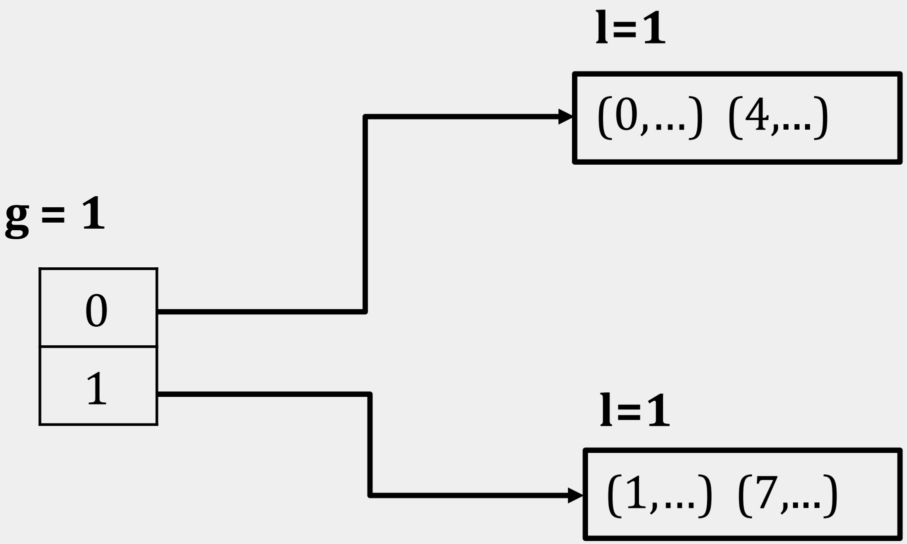
EXTENDIBLE HASHING: INSERT

If the bucket is full, split the bucket and redistribute the entries



EXAMPLE

each page can hold at most two records

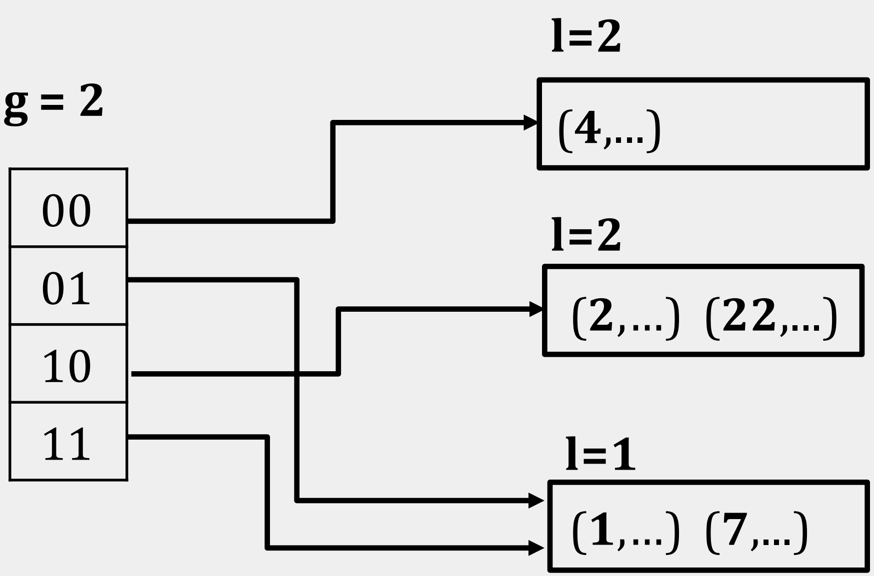


We always have: global depth >= local depth

EXAMPLE

insert: (**22**,…)

- The catalog doubles in size
- Global depth becomes 2



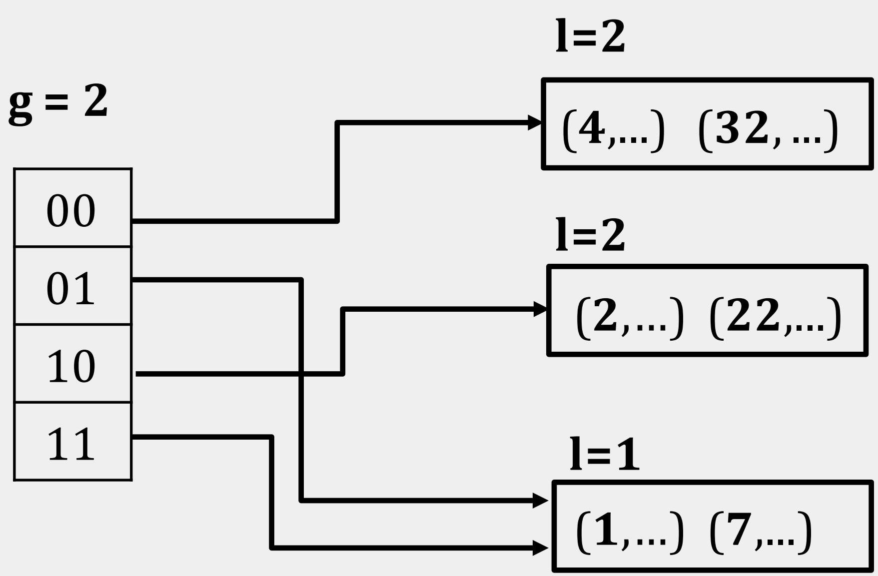
The bucket is split into two buckets with local depth 2

This bucket remains the same

EXAMPLE

insert: (**32**,…)

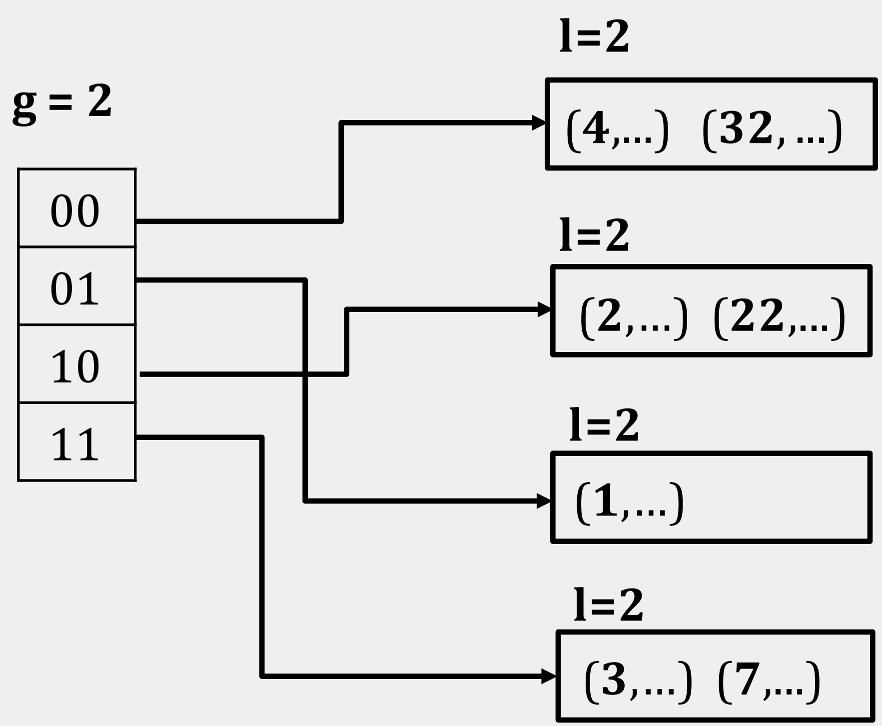
There is space in the bucket so nothing changes!



EXAMPLE

Since local depth is smaller than global, no need to change the directory size!

insert: (**3**,…)



The bucket is split into two

EXTENDIBLE HASHING: DELETE

- Locate the bucket of the record and remove it
- If the bucket becomes empty, it can be removed (and update the directory)
- Two buckets can also be coalesced together if the sum of the entries fit in a single bucket
- Decreasing the size of the directory can also be done, but it is expensive

MORE ON EXTENDIBLE HASHING

- How many disk accesses for equality search?
  - One if directory fits in memory, else two
- Directory grows in spurts, and, if the distribution of hash values is skewed, the directory can grow very large
- We may need overflow pages when multiple entries have the same hash value!