Database Systems (資料庫系統)

December 6/7, 2006

Lecture #9

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Announcement

- Next week reading: Chapter 12
- Hand in your assignment #3.
- Assignment #4 will be on the course homepage and again due in 2 weeks.

2

The Story of African Lion and Zebra

every morning, a zebra wakes up,

it knows that it must run faster than the fastest lion, or it will be eaten;

every morning, a lion wakes up,

it knows that it must run faster than the slowest zebra, or it will starve to death;

it does not matter whether you are a zebra or a lion,

when the sun comes up,

you better run fast.

3

Hash-Based Indexing

Chapter 11

4

Introduction

- Hash-based indexes are best for equality selections. Cannot support range searches.
  - Equality selections are useful for natural join operations.

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Review: Tree Index

- ISAM vs. B+ trees.
  - What is the main difference between them?
    - Static vs. dynamic structure
  - What is the tradeoff between them?
    - Graceful table growth/shrink vs. concurrency performance

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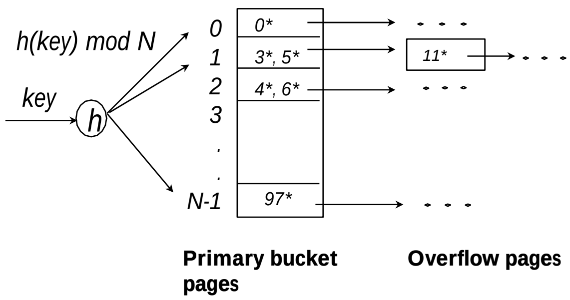
Similar tradeoff for hashing

- Possible to exploit the tradeoff between dynamic structure for better performance?

- Static hashing technique
- Two dynamic hashing techniques
  - Extendible Hashing
  - Linear Hashing

Basic Static Hashing

- # primary pages fixed, allocated sequentially, never de-allocated; overflow pages if needed.
- **h**(*k*) mod N = bucket to which data entry with key *k* belongs. (N = # of buckets)



Static Hashing (Contd.)

- Buckets contain data entries.
- Hash function takes search key field of record r and distribute values over range 0 ... N-1.
  - ***h***(*key*) = *(a * key + b)* usually works well.
  - *a* and *b* are constants; lots known about how to tune **h**.
- Cost for insertion/delete/search: 2/2/1 disk page I/Os (no overflow chains).

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What is the performance problem for static hashing?

- Long overflow chains can develop and degrade performance.
  - Why poor performance? Scan through overflow chains linearly.
- How to fix this problem?
  - Extendible and Linear Hashing: Dynamic techniques to fix this problem.

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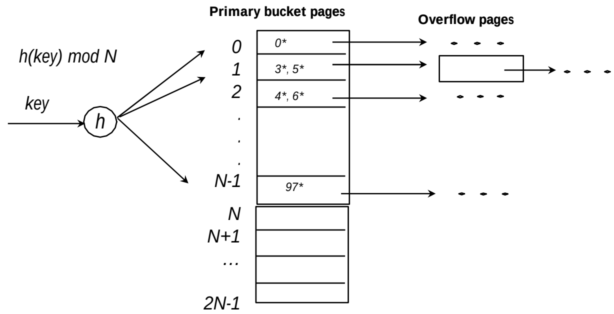
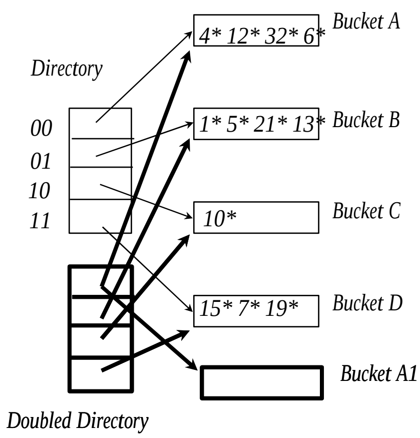
Extendible Hashing

- Simple Solution – remove overflow chain.
- When bucket (primary page) becomes full, ..
  - Re-organize file by adding (doubling) buckets.
- What is the cost concern in doubling buckets?
  - High cost: rehash all entries - reading and writing all pages is expensive!



How to minimize the rehashing cost?

- Use another level of indirection
  - Directory of pointers to buckets
- Insert 0 (00)
  - Double buckets only double the directory (no rehashing)
  - Split just the bucket that overflowed!
- What is cost here?



Extendible Hashing

- Directory much smaller than file, so doubling much cheaper. Only one page of data entries is split.
- How to adjust the hash function?
  - Before doubling directory
    - h(r) $\rightarrow$ 0..N-1 buckets.
  - After doubling directory?
    - h(r) $\rightarrow$ 0 .. 2N-1 (the range is doubled)

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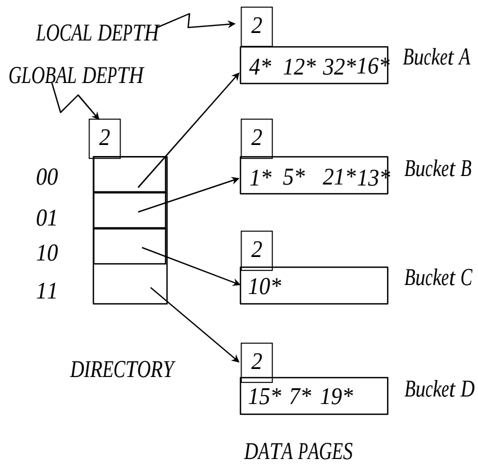
Example

- Directory is array of size 4.
- Need to know current #bits used in the hash function
  - Global Depth
- May need to know #bits used to hash a specific bucket
  - Local Depth
- Can global depth < local depth?



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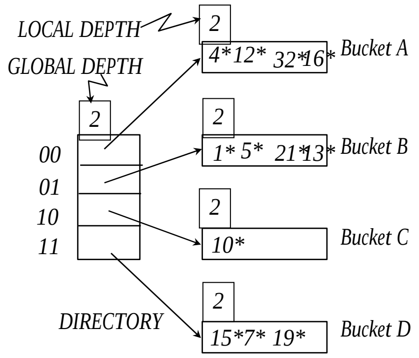
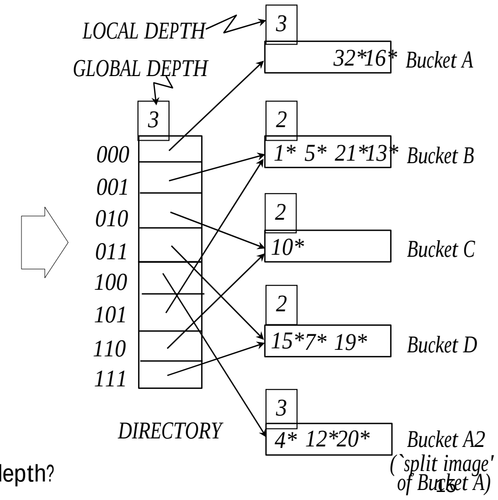
Insert 20 (10100): Double Directory





Know the difference between double directory & split bucket.
double directory:
-Increment global depth
-Rehash bucket A
-Increment local depth, why track local depth?

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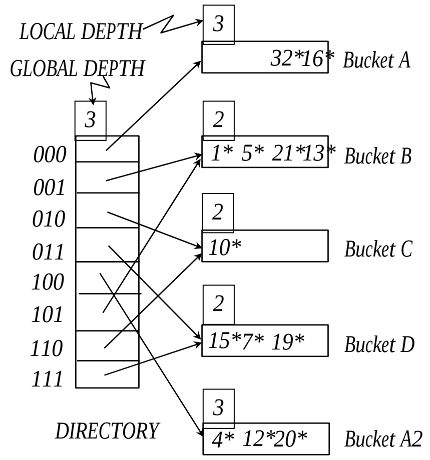
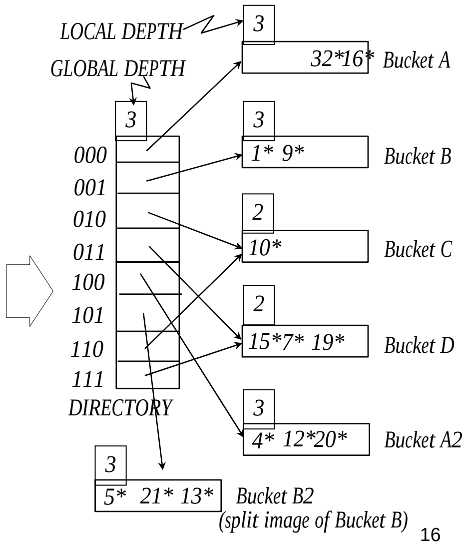
Insert 9 (1001): only Split Bucket





Only split bucket:
-Rehash bucket B
-Increment local depth

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Points to Note

- What is the global depth of directory?
  - Max # of bits needed to tell which bucket an entry belongs to.
- What is the local depth of a bucket?
  - # of bits used to determine if an entry belongs to this bucket.
- When does bucket split cause directory doubling?
  - Before insert, bucket is full & local depth = global depth.
- How to efficiently double the directory?
  - Directory is doubled by copying it over and `fixing' pointer to split image page.
  - Note that you can do this only by using the least significant bits in the directory.

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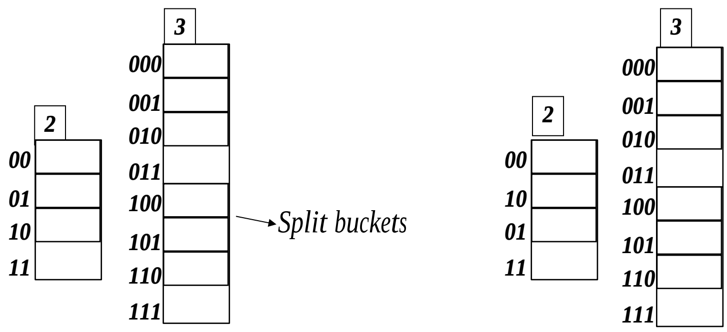
Directory Doubling

Why use least significant bits in directory?
⇔ Allows for doubling via copying!



Least Significant *vs.* *Most Significant*

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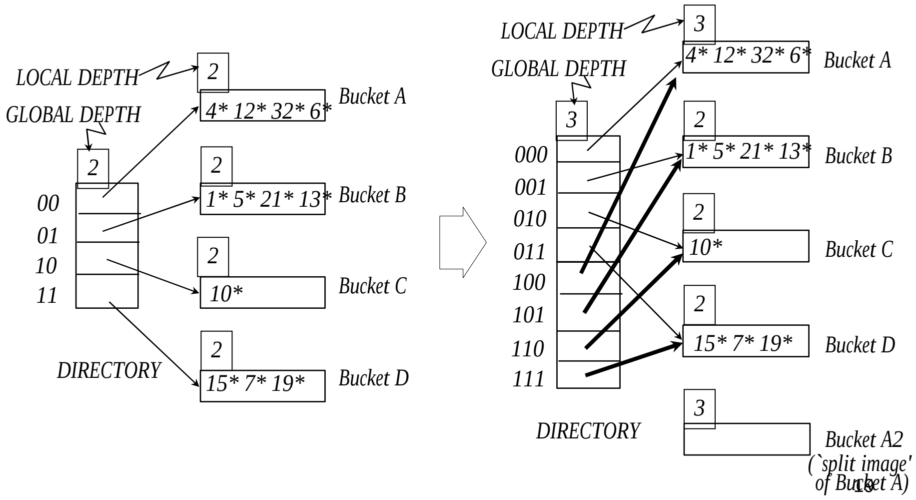
Directory Copying via Insertion 20 (10100)



Comments on Extendible Hashing

- If directory fits in memory, equality search answered with one disk access; else two.
- What is the problem with extendible hashing?
  - Consider if the distribution of hash values is skewed (concentrates on a few buckets)
  - Directory can grow large.
- Can you come up with one insertion leading to multiple splits?

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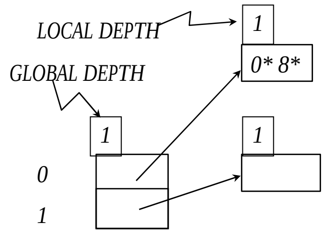
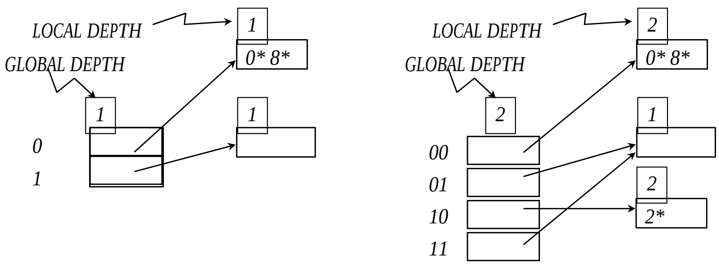
Skewed data distribution (multiple splits)

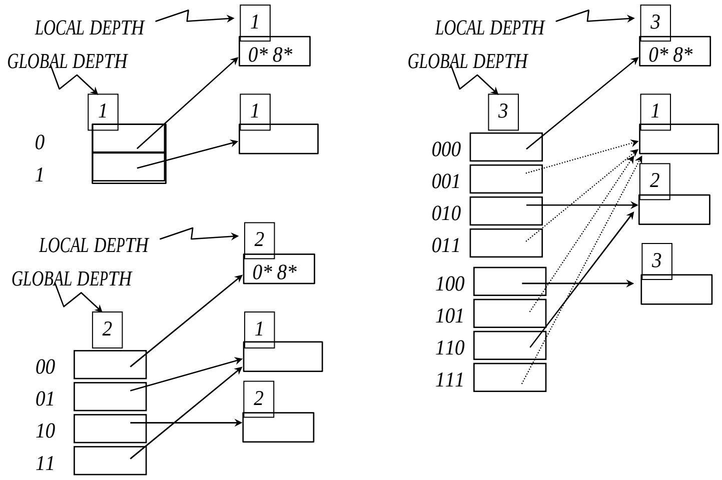
- Assume each bucket holds two data entries
- Insert 2 (binary 10) – how many times of dir doubling?
- Insert 16 (binary 10000) – how many times of dir doubling?
- How to solve this data skew problem?



Insert 2 (10)



Insert 16 (10000)



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Comments on Extendible Hashing

- Delete: If removal of data entry makes bucket empty, can be merged with `split image'. If each directory element points to same bucket as its split image, can halve directory.

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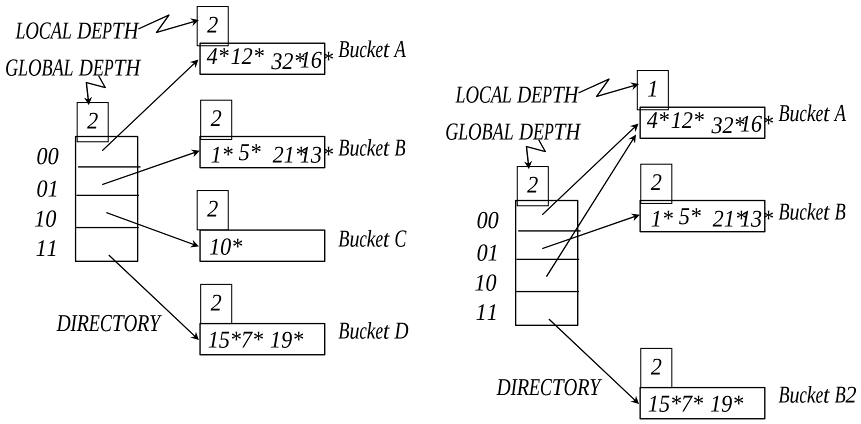
Delete 10*



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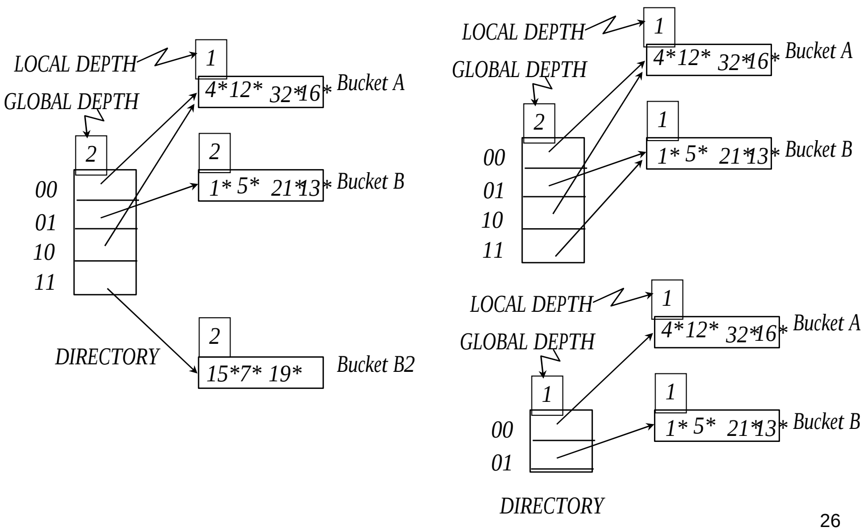
Delete 15*, 7*, 19*



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Linear Hashing (LH)

- Another dynamic hashing scheme, as an alternative to Extendible Hashing.
- What are problems in static/extendible hasing?
  - Static hashing: long overflow chains
  - Extendible hashing: data skew causing large directory
- Is it possible to come up with a more balanced solution?
  - Shorter overflow chains than static hashing
  - No need for directory in extendible hashing
    - How do you get rid of directory (indirection)?

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Linear Hashing (LH)

- Basic Idea:
  - Pages are split when overflows occur – but not necessarily the page with the overflow.
  - Splitting occurs in turn, in a round robin fashion.
    - one by one from the first bucket to the last bucket.
- Use a family of hash functions $\mathbf{h}_0$, $\mathbf{h}_1$, $\mathbf{h}_2$, ...
  - Each function's range is twice that of its predecessor.
  - When all the pages at one level (the current hash function) have been split, a new level is applied.
  - Splitting occurs gradually
  - Primary pages are allocated in order & consecutively.

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Linear Hashing Verbal Algorithm

- Initial Stage.
  - The initial level distributes entries into N_0 buckets.
  - Call the hash function to perform this h_0.
- Splitting buckets.
  - If a bucket overflows its primary page is chained to an overflow page (same as in static hashing).
  - Also when a bucket overflows, some bucket is split.
    - The first bucket to be split is the first bucket in the file (*not* necessarily the bucket that overflows).
    - The next bucket to be split is the second bucket in the file … and so on until the *N*th. has been split.
    - When buckets are split their entries (including those in overflow pages) are distributed using h_1.
  - To access split buckets the next level hash function (h_1) is applied.
  - h_1 maps entries to $2N_0$ (or N_1)buckets.

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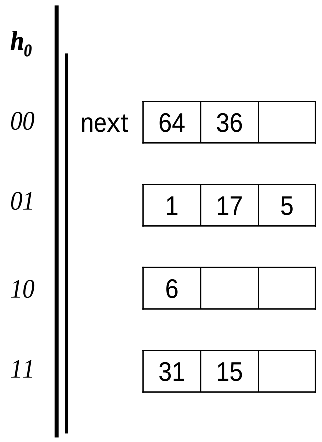
Linear Hashing Example



- Initially, the index level equal to 0 and N_0 equals 4 (three entries fit on a page).
- h_0 range = 4 buckets
- Note that ***next*** indicates which bucket is to split next. (Round Robin)
- Now consider what happens when 9 (1001) is inserted (which will not fit in the second bucket).

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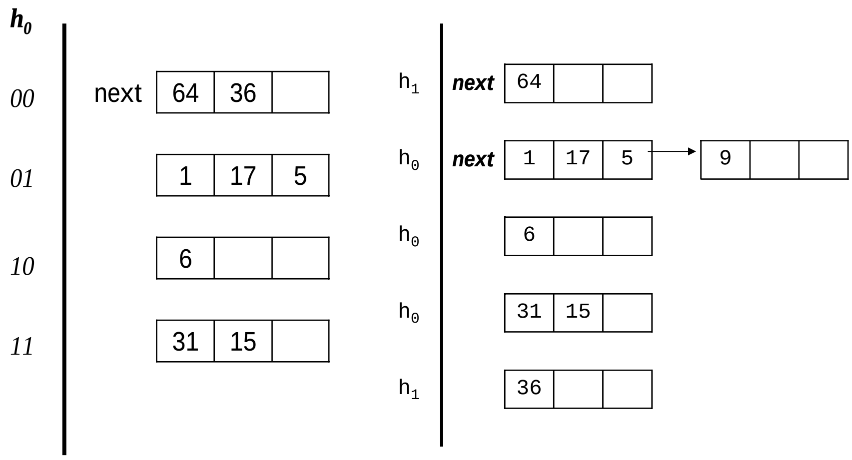
Insert 9 (1001)



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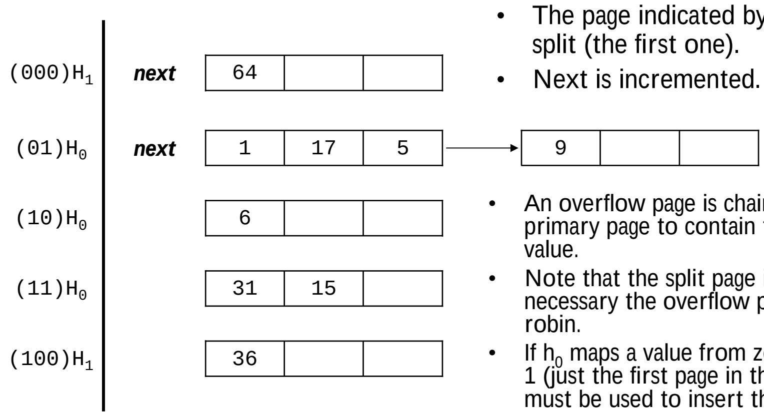
Linear Hashing Example 2

- The page indicated by next is split (the first one).
- Next is incremented.



- An overflow page is chained to the primary page to contain the inserted value.
- Note that the split page is not necessary the overflow page – round robin.
- If h_0 maps a value from zero to next – 1 (just the first page in this case), h_1 must be used to insert the new entry.
- Note how the new page falls naturally into the sequence as the fifth page.

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Insert 8 (1000), 7(111), 18(10010), 14(1100)

(000)H_1		64	8				
(01)H_0	***next***	1	17	5	9		
(10)H_0		6	18				
(11)H_0		31	15	7			
(100)H_1		36	14				

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Before Insert 11 (1011)

(000)H_1		64	8				
(01)H_0	***next***	1	17	5	9		
(10)H_0		6	18				
(11)H_0		31	15	7			
(100)H_1		36	14				

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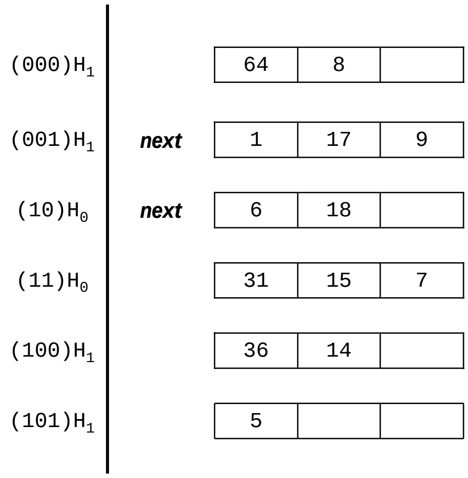
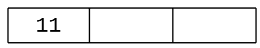
After Insert 11 (1011)



Which hash function (h0 or h1) for searching 9?

How about searching for 18?



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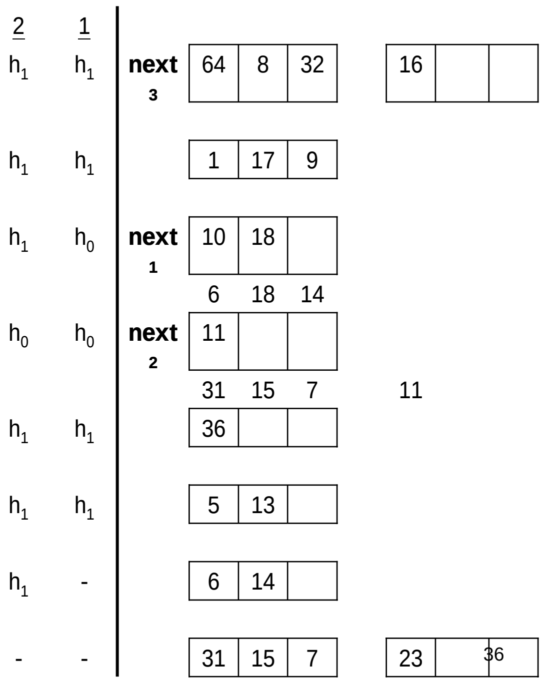
Linear Hashing

- Insert 32, $\underline{16}_2$
- Insert 10, 13, $\underline{23}_3$
- After the 2nd. split the base level is 1 (N_1 = 8), use h_1.
- Subsequent splits will use h_2 for inserts between the first bucket and *next*-1.



Notes for Linear Hashing

- Why linear hashing does not need a directory but extendible hashing does need it?
  - Consider finding i-th bucket
  - New buckets are created in order (sequentially, i.e., round robin) in linear hashing
- Level progression:
  - Once all *N*i buckets of the current level (i) are split the hash function h_i is replaced by h_{i+1}.
  - The splitting process starts again at the first bucket and h_{i+2} is applied to find entries in split buckets.

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LH Described as a Variant of EH

- Can you describe linear hashing using extendible hashing (EH)?
  - Begin with an EH index where directory has *N* elements.
  - Use overflow pages, split buckets round-robin.
  - First split is at bucket 0. (Imagine directory being doubled at this point.) But elements <1,*N*+1>, <2,*N*+2>, ... are the same. So, need only create directory element *N*, which differs from 0, now.
    - When bucket 1 splits, create directory element *N*+1, etc.
- So, directory can double gradually. Also, primary bucket pages are created in order. If they are *allocated* in sequence too (so that finding i'th is easy), we actually don't need a directory! Voila, LH.

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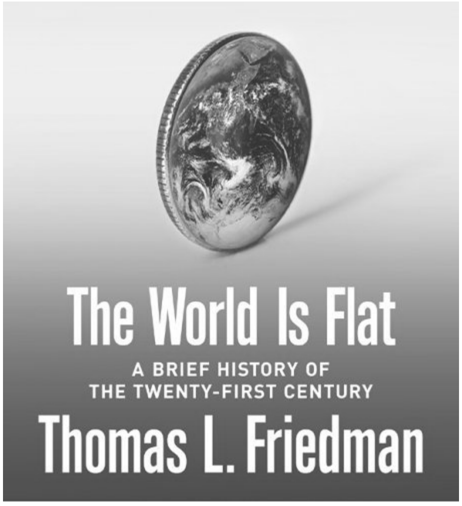

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The New World is Flat

- With computer and network, the playing field is being leveled across the world.
- There is no end to what can be done by whom
  - Before: manufacturing products (Made in Taiwan, Made in China)
  - Now: anything including service industry
- This is called outsourcing
- The rule of Capitalist economy:
  - Work goes to the place where it can be done cheapest and most efficient

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Outsourcing Examples

- Customer services moving to call centers in India
  - Credit cards, banks, insurance, Microsoft, …
- Radiologists in India and Australia
- E-tutoring
- Jetblue & homesourcing
- Tax preparation outsourcing
- MacDonald Flatfries and burgers
- Kenichi Ohmae (大前研一)

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Outsourcing and ME in Taiwan?

- So anyone on this planet may be replaced by anyone on this planet for cheaper and more efficient
  - Yes, for any jobs – high/low tech, manufacturing/service
  - Scaring? Consider massive amount of smart & cheap labors in China and India
- Oops … this is happening NOW here in Taiwan!
- So one can compete or collaborate globally with anyone on this planet -> opportunity.

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Globalization …

- Globalization 1.0
  - Columbus
  - Players: nations with big guns & muscles
- Globalization 2.0
  - Coke and Macdonald
  - Players: a multi-national corporation with global market and labor & industrial revolution & transportation & telephones
- Globalization 3.0
  - Players: You and Me
  - Enablers?

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