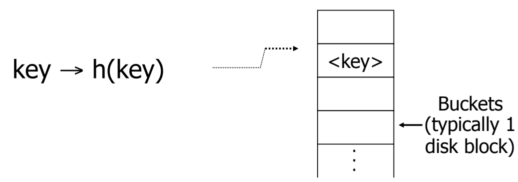
CS 525: Advanced Database Organization

05: Hashing and More

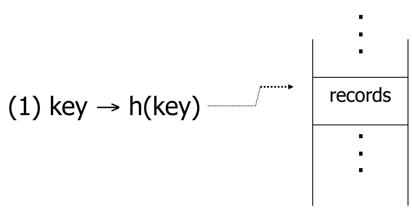
Boris Glavic

Slides: adapted from a course taught by Hector Garcia-Molina, Stanford InfoLab

Hashing



Two alternatives



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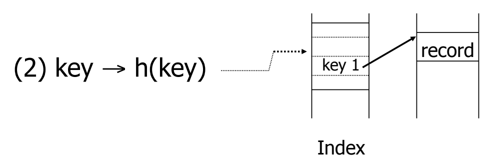

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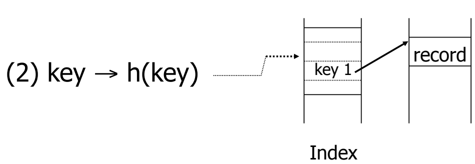

- Alt (2) for "secondary" search key

Example hash function

- Key = 'x_1 x_2 … x_n' *n* byte character string
- Have *b* buckets
- h: add $x_1 + x_2 + \ldots.. x_n$
  - compute sum modulo *b*

- This may not be best function …
- Read Knuth Vol. 3 if you really need to select a good function.

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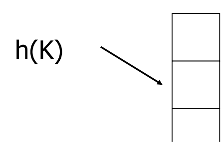
Good hash function: ☞ Expected number of keys/bucket is the same for all buckets

<u>Within a bucket:</u>

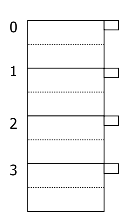
- Do we keep keys sorted?
- Yes, if CPU time critical & Inserts/Deletes not too frequent

<u>Next:</u> example to illustrate inserts, overflows, deletes



<u>EXAMPLE</u> 2 records/bucket

INSERT:
h(a) = 1
h(b) = 2
h(c) = 1
h(d) = 0



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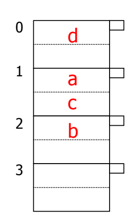

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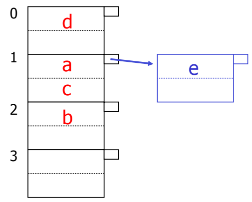
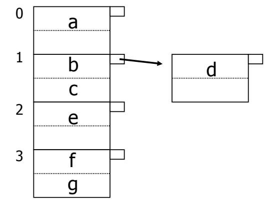


EXAMPLE: deletion

Delete:
e
f



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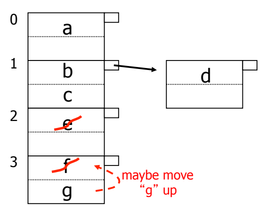

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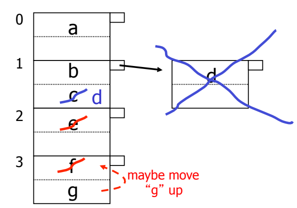

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  Utilization = $\frac{\text{\# keys used}}{\text{total \# keys that fit}}$

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- If < 50%, wasting space
- If > 80%, overflows significant
  ↳ depends on how good hash function is & on # keys/bucket

How do we cope with growth?

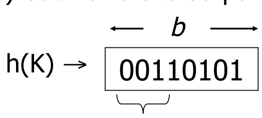
- Overflows and reorganizations
- Dynamic hashing

How do we cope with growth?

- Overflows and reorganizations
- Dynamic hashing
    - Extensible
    - Linear

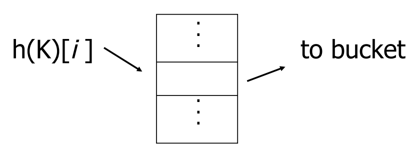
Extensible hashing: two ideas

(a) Use *i* of *b* bits output by hash function

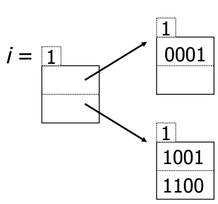


use *i* → grows over time….

(b) Use directory



Example: h(k) is 4 bits; 2 keys/bucket



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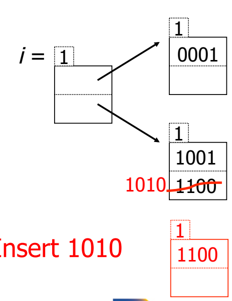

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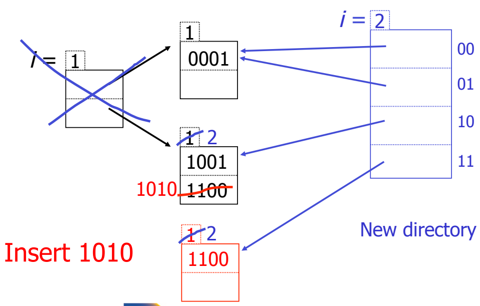
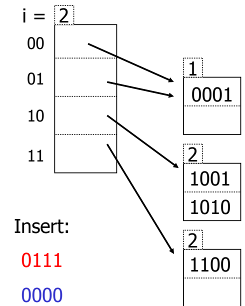


Example continued



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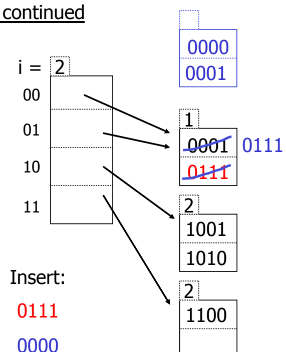

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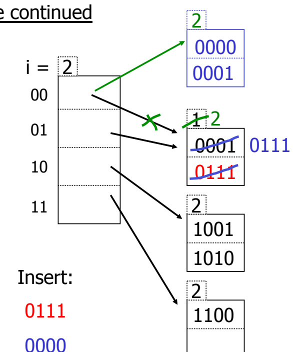

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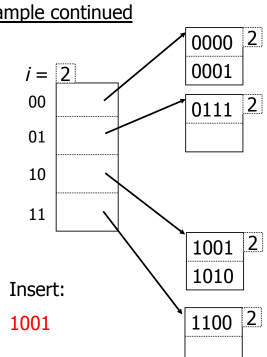

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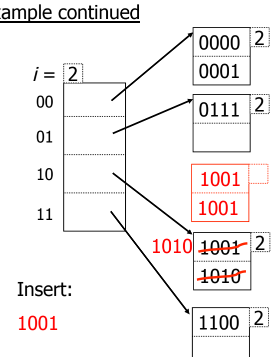

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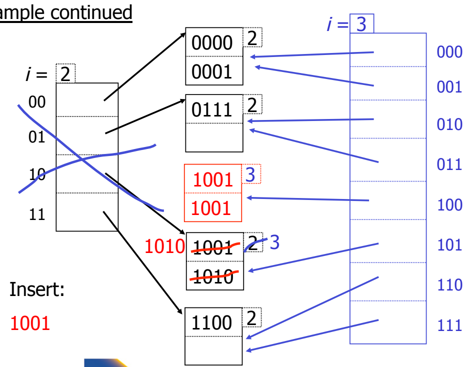


Insert:
1001

Extensible hashing: deletion

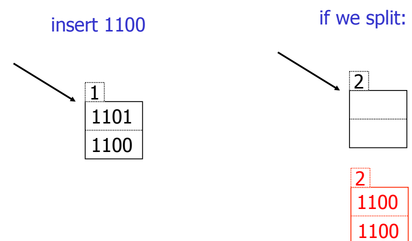
- No merging of blocks
- Merge blocks
  and cut directory if possible
  (Reverse insert procedure)

Deletion example:

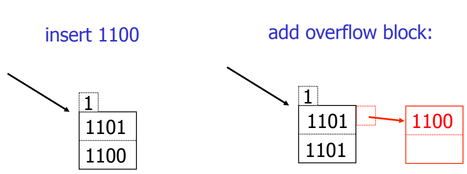
- Run thru insert example in reverse!

Note: Still need overflow chains

- Example: many records with duplicate keys



Solution: overflow chains



Summary Extensible hashing

⊕ Can handle growing files
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⊖ Indirection

(Not bad if directory in memory)

⊖ Directory doubles in size

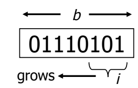
(Now it fits, now it does not)

Linear hashing

- Another dynamic hashing scheme

Two ideas:

(a) Use *i* low order bits of hash



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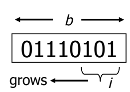
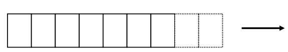
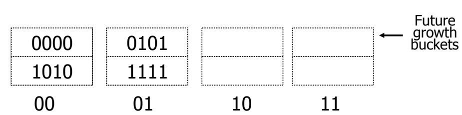


(b) File grows linearly



Example *b*=4 bits, *i* =2, 2 keys/bucket



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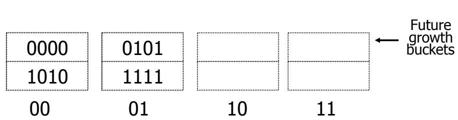

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Rule If h(k)[*i*] ≤ *m*, then
look at bucket h(k)[i]
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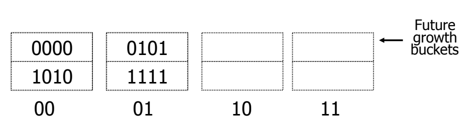
- insert 0101



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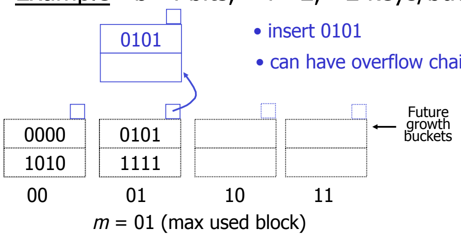
- can have overflow chains!



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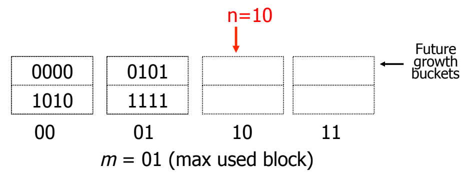
Note

- In textbook, n is used instead of m
- n=m+1



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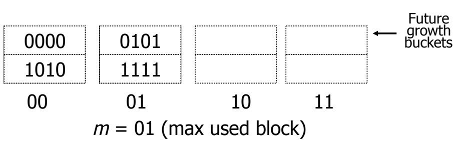

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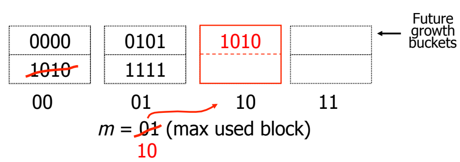

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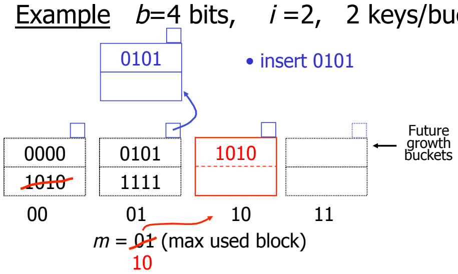

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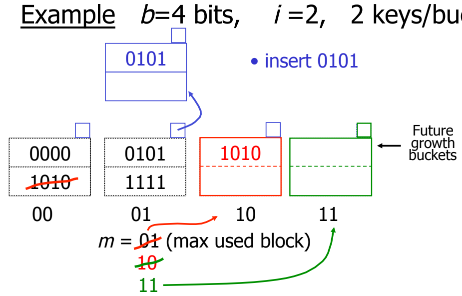

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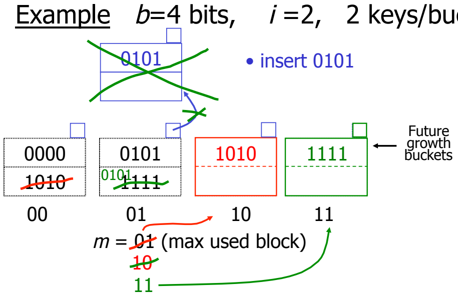

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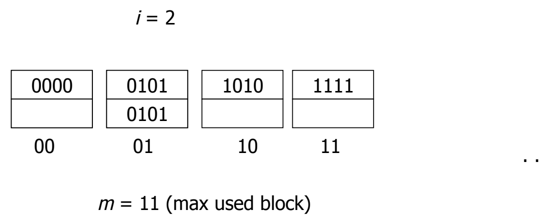

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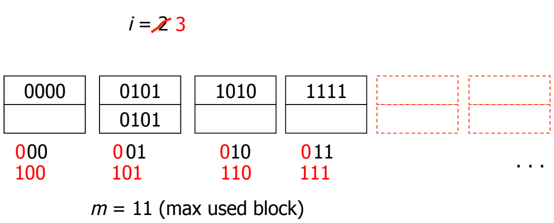

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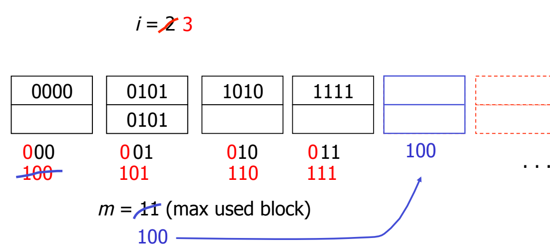

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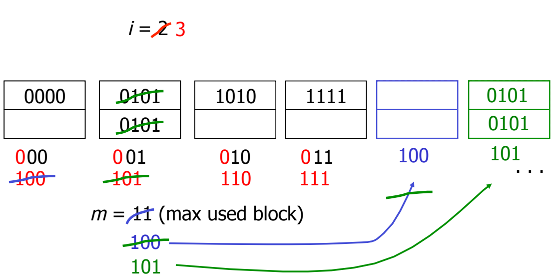

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- If U > threshold then increase *m* (and maybe *i*)

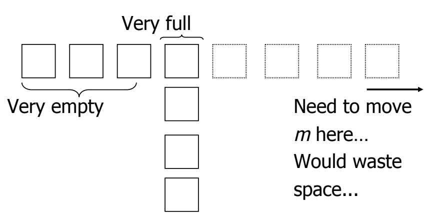
Summary Linear Hashing

⊕ Can handle growing files
  - with less wasted space
  - with no full reorganizations

⊕ No indirection like extensible hashing

⊖ Can still have overflow chains

Example: BAD CASE



Summary

Hashing
- How it works
- Dynamic hashing
  - Extensible
  - Linear

Next:

- Indexing vs Hashing
- Index definition in SQL
- Multiple key access

Indexing vs Hashing

- Hashing good for probes given key

e.g.,
```
SELECT …
FROM R
WHERE R.A = 5
```

-> **Point Queries**

Indexing vs Hashing

- INDEXING (Including B Trees) good for
  Range Searches:
  e.g., SELECT
  FROM R
  WHERE R.A > 5

-> **Range Queries**

Index definition in SQL

- Create index name on rel (attr)
- Create unique index name on rel (attr)
  → defines candidate key

- Drop INDEX name

Note CANNOT SPECIFY TYPE OF INDEX
(e.g. B-tree, Hashing, …)
OR PARAMETERS
(e.g. Load Factor, Size of Hash,...)

... at least in standard SQL...

Vendor specific extensions allow that

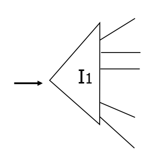
Note ATTRIBUTE LIST ⇒ MULTIKEY INDEX
(next)
e.g., CREATE INDEX foo ON R(A,B,C)

Multi-key Index

Motivation: Find records where
DEPT = “Toy” AND SAL > 50k

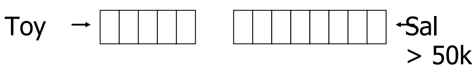
Strategy I:

- Use one index, say Dept.
- Get all Dept = “Toy” records
  and check their salary



Strategy II:

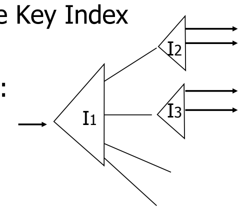
- Use 2 Indexes; Manipulate Pointers



Strategy III:

- Multiple Key Index

One idea:



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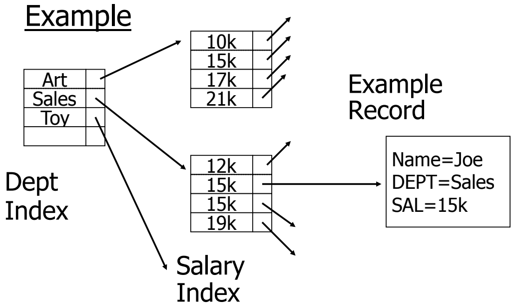
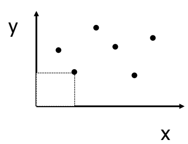


For which queries is this index good?

- ☐ Find RECs Dept = "Sales" $\wedge$ SAL=20k
- ☐ Find RECs Dept = "Sales" $\wedge$ SAL $\geq$ 20k
- ☐ Find RECs Dept = "Sales"
- ☐ Find RECs SAL = 20k

Interesting application:

- Geographic Data

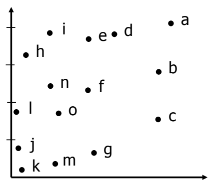


DATA:
<X1,Y1, Attributes>
<X2,Y2, Attributes>
⋮

Queries:

- What city is at <Xi,Yi>?
- What is within 5 miles from <Xi,Yi>?
- Which is closest point to <Xi,Yi>?

Example



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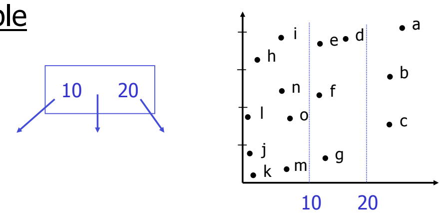

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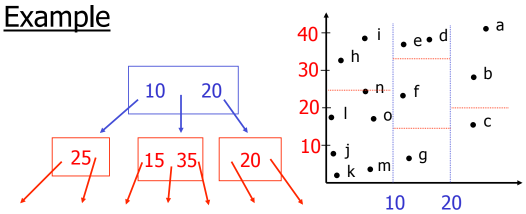

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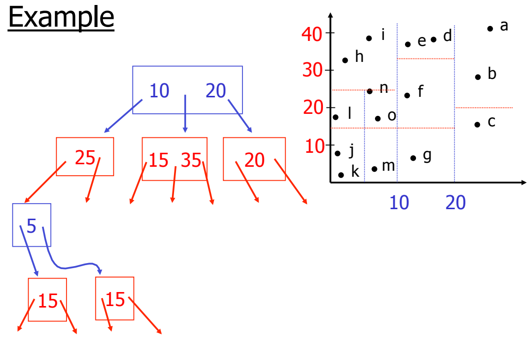

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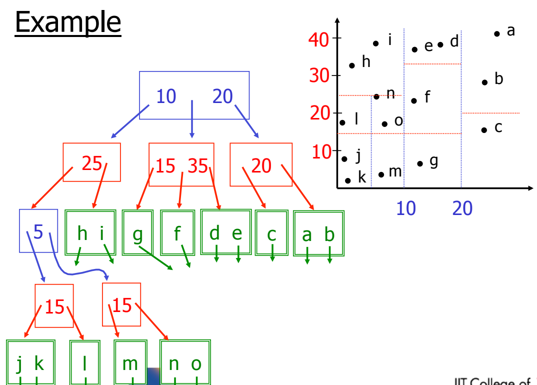

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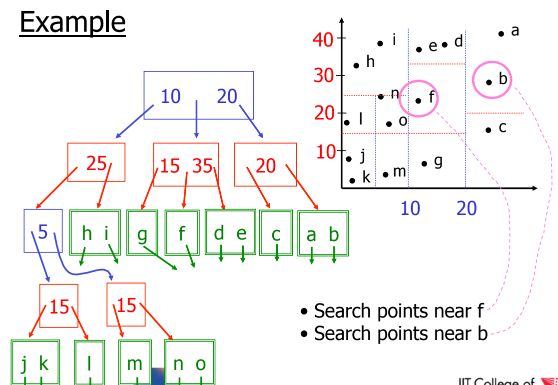

- Search points near f
- Search points near b

Queries

- Find points with Yi > 20
- Find points with Xi < 5
- Find points "close" to i = <12,38>
- Find points "close" to b = <7,24>

Next

- Even more index structures ☺