Spring 2017

BITMAP INDEXING

Motivation

Consider the following table:

```
  CREATE TABLE Tweets (
     uniqueMsgID INTEGER,       -- unique message id
     tstamp      TIMESTAMP,     -- when was the tweet posted
     uid         INTEGER,       -- unique id of the user
     msg         VARCHAR (140), -- the actual message
     zip         INTEGER,       -- zipcode when posted
     retweet     BOOLEAN        -- retweeted?
     );
```

In the past, we have used a B+-tree for the uid and the zip values.

In a B+-tree, how many bytes do we use for each record?

Can we do better, i.e. an index with lower storage overhead?
Especially for attributed with small domain cardinalities?

Bit-based indices: Two flavors

a) Bitmap indices and

b) Bitslice indices

Bitmap Indices

- Consider building an index to answer equality queries on the retweet attribute
- Issues with building a B-tree:
  - Three distinct values: True, False, NULL
  - Lots of duplicates for each distinct value
  - Sort of an odd B-tree with three long rid lists
- Bitmap Index: Build three bitmap arrays (stored on disk), one for each value.
  - The ith bit in each bitmap correspond to the ith tuple

    (need to map ith position to a rid)

Bitmap Example

Table (stored in a heapfile)

uniqueMsgID	…	zip	retweet
1		11324	Y
2		53705	Y
3		53706	N
4		53705	NULL
5		90210	N
…	…	…	…
1,0000,000,000		53705	Y

Bitmap index on "retweet"

R-Yes	R-No
1	0
1	0
0	1
0	0
0	1
…	…
1	0

```
SELECT * FROM Tweets WHERE retweet = ‘N’
```

1. Scan the R-No Bitmap file
2. For each bit set to 1, compute the tuple #
3. Fetch the tuple # (s)

Critical Issue

- Need an efficient way to compute a bit position
  - – Layout the bitmap in page id order.
- Need an efficient way to map a bit position to a record id.
  How?
  1. If you fix the # records per page in the heapfile
  2. And lay the pages out so that page #s are sequential and increasing
  3. Then can construct rid (page-id, slot#)
     - page-id = Bit-position / #records-per-page
     - slot# = Bit-position % #records-per-page

Implications of #1?

Other Queries

Table (stored in a heapfile)

uniqueMsgID	…	zip	retweet
1		11324	Y
2		53705	Y
3		53706	N
4		53705	NULL
5		90210	N
…	…	…	…
1,0000,000,000		53705	Y

Bitmap index on "retweet"

R-Yes	R-No	R-Null
1	0	0
1	0	0
0	1	0
0	0	1
0	1	0
…	…	…
1	0	0

```
SELECT COUNT(*) FROM Tweets WHERE retweet = ‘N’
```

```
SELECT * FROM Tweets WHERE retweet IS NOT NULL
```

Storing the Bitmap index

- One bitmap for each value, and one for Nulls
- Need to store each bitmap
- Simple method: 1 file for each bitmap
- Can compress the bitmap!

Index size?

When is a bitmap index more space efficient than a B+-tree?

Bit-sliced Index: Motivation

(Re)consider the following table:

```
CREATE TABLE Tweets (
   uniqueMsgID INTEGER,       -- unique message id
   tstamp      TIMESTAMP,     -- when was the tweet posted
   uid         INTEGER,       -- unique id of the user
   msg         VARCHAR (140), -- the actual message
   zip         INTEGER,       -- zipcode when posted
   retweet     BOOLEAN        -- retweeted?
   );
```

```
SELECT * FROM Tweets WHERE zip = 53706
```

Would we build a bitmap index on zipcode?

Bit-sliced index

Why do we have 17 bits for zipcode?

Table

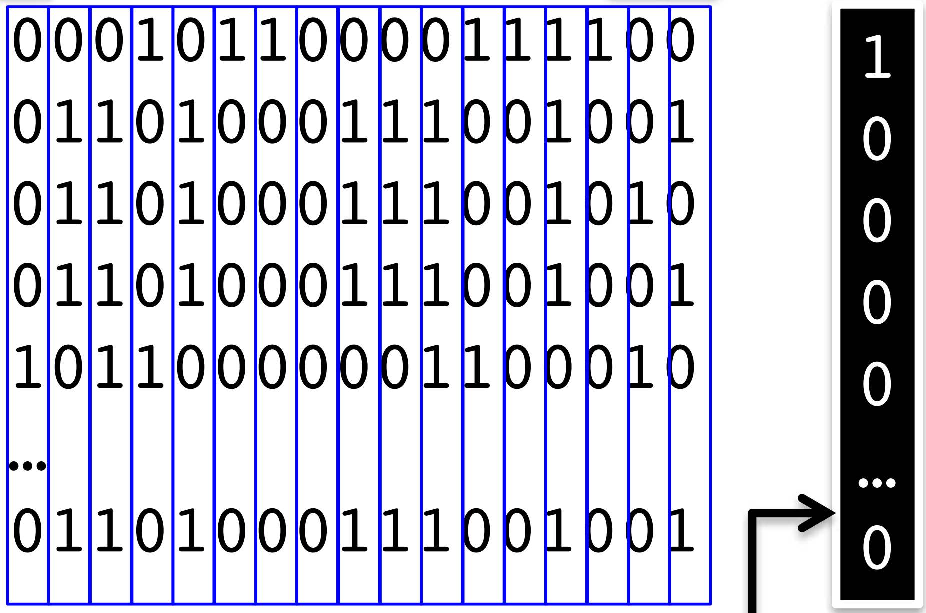
uniqueMsgID	…	zip	retweet
1		11324	Y
2		53705	Y
3		53706	N
4		53705	NULL
5		90210	N
…	…	…	…
1,0000,000,000		53705	Y

Slice 16

Bit-sliced index (1 slice per bit)

Slice 1

Slice 0



```
00010110000111100
01101000111001001
01101000111001010
01101000111001001
10110000001100010
…
01101000111001001
```

```
1
0
0
0
0
…
0
```

Query evaluation: Walk through each slice constructing a **result bitmap**

e.g. zip ≤ 11324, skip entries that have 1 in the first three slices (16, 15, 14)

Are we missing anything in the bit-sliced index above?

(Null bitmap is not shown)

Bitslice Indices

- Can also do aggregates with Bitslice indices
  - E.g. SUM(attr): Add bit-slice by bit-slice.

    First, count the number of 1s in the **slice17,** and multiply the count by 2^{17}

    Then, count the number of 1s in the **slice16**, and multiply the count by …

- Store each slice using methods like what you have for a bitmap.
  - Note once again can use compression

Bitmap v/s Bitslice

- Bitmaps better for low cardinality domains
- Bitslice better for high cardinality domains
- Generally easier to “do the math” with bitmap indices