OLAP Indexes

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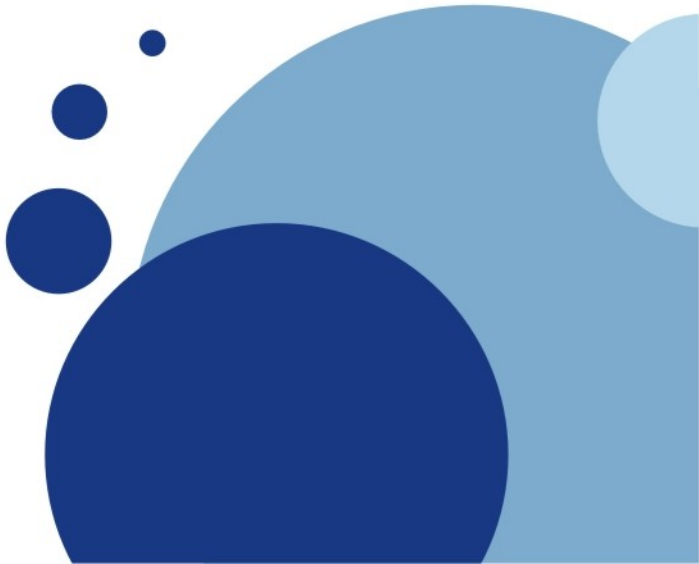


Indexes

- Indexes
  - B-trees, hash tables,
  - Grids, quad-trees, R-trees (spatial data)
- OLAP indexes
  - Bitmaps, inverted lists,
  - Join Indexes, Bitmap join indexes
  - Column store indexes
- ROWID
  - physical address of a row
  - Oracle
    - OOOOOO.FFF.BBBBBB.RRR

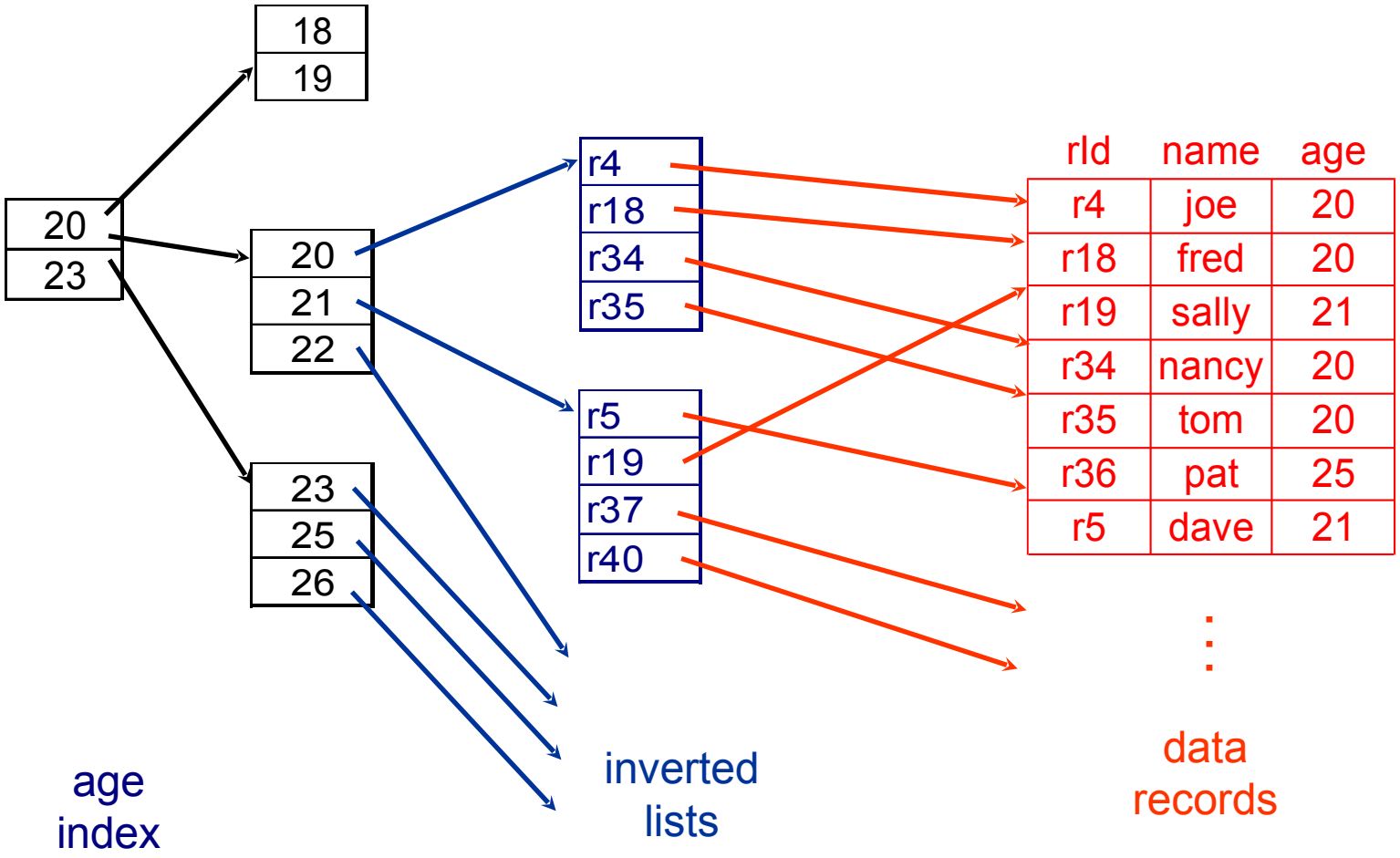
OOOOOO is the object ID

FFF is the file number

BBBBBB is the block number

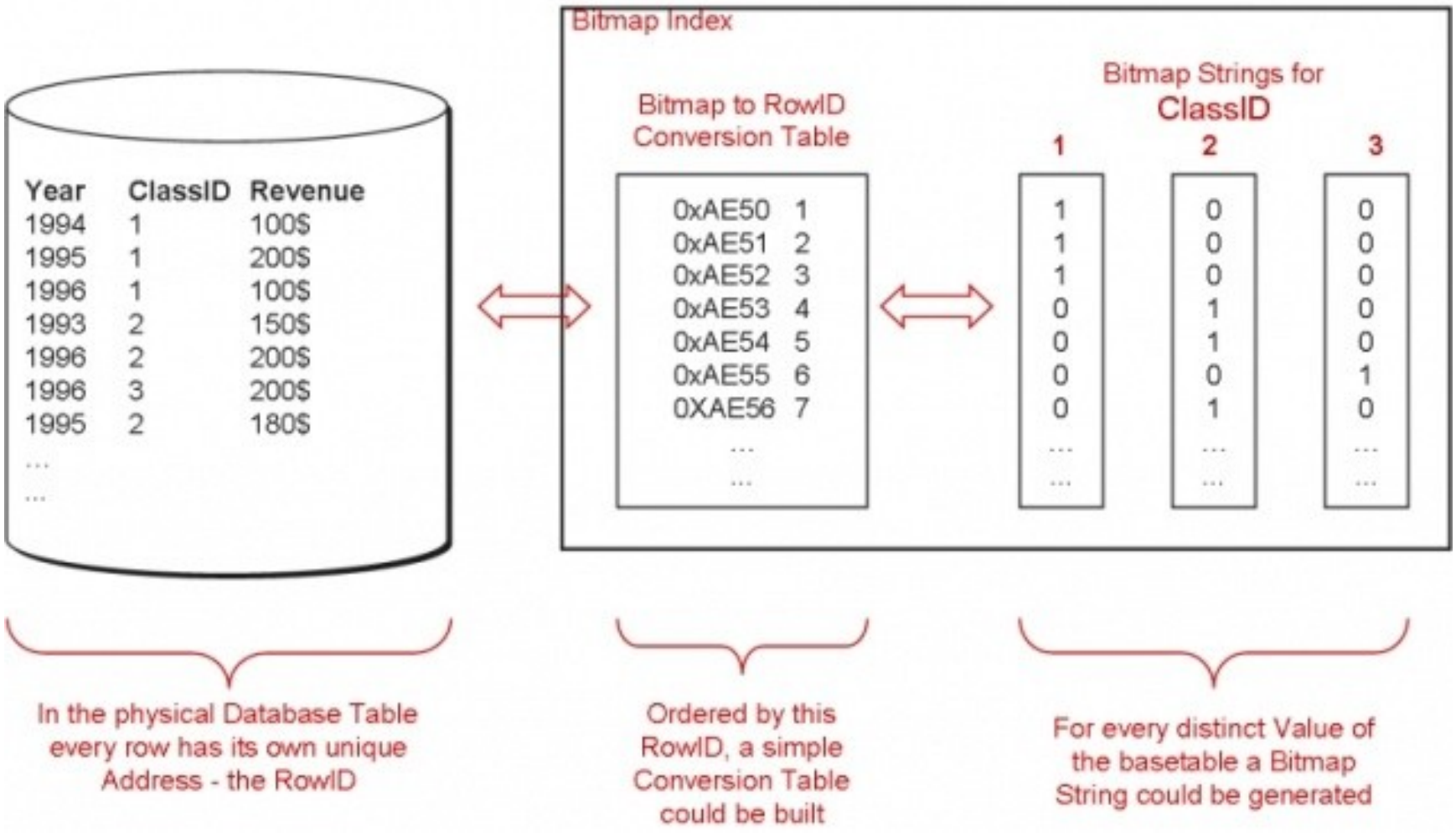
RRR is the row number

Inverted List Index



By Hector Garcia Molina: Data Warehousing and OLAP

Bitmap Index



Operations on Bit Vectors

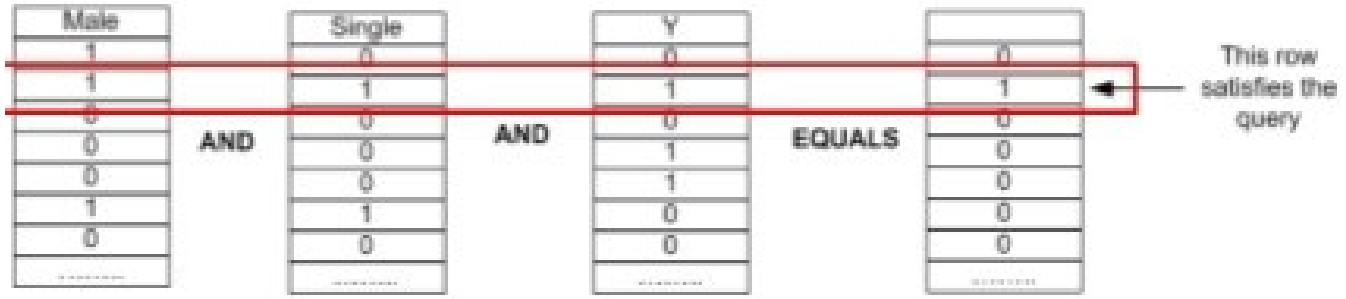
Gender	MaritalStatus	ChildrenYN	Income	HomeOwner
M	Married	N	120000	N
M	Single	N	80000	Y
F	Divorced	Y	75000	N
F	Married	Y	70000	Y
F	Married	Y	130000	Y
M	Single	Y	45000	N
F	Married	N	42000	N
.....	.....	.....	.....	.....

Male	Female
1	0
1	0
0	1
0	1
0	1
1	0
0	1
.....	.....

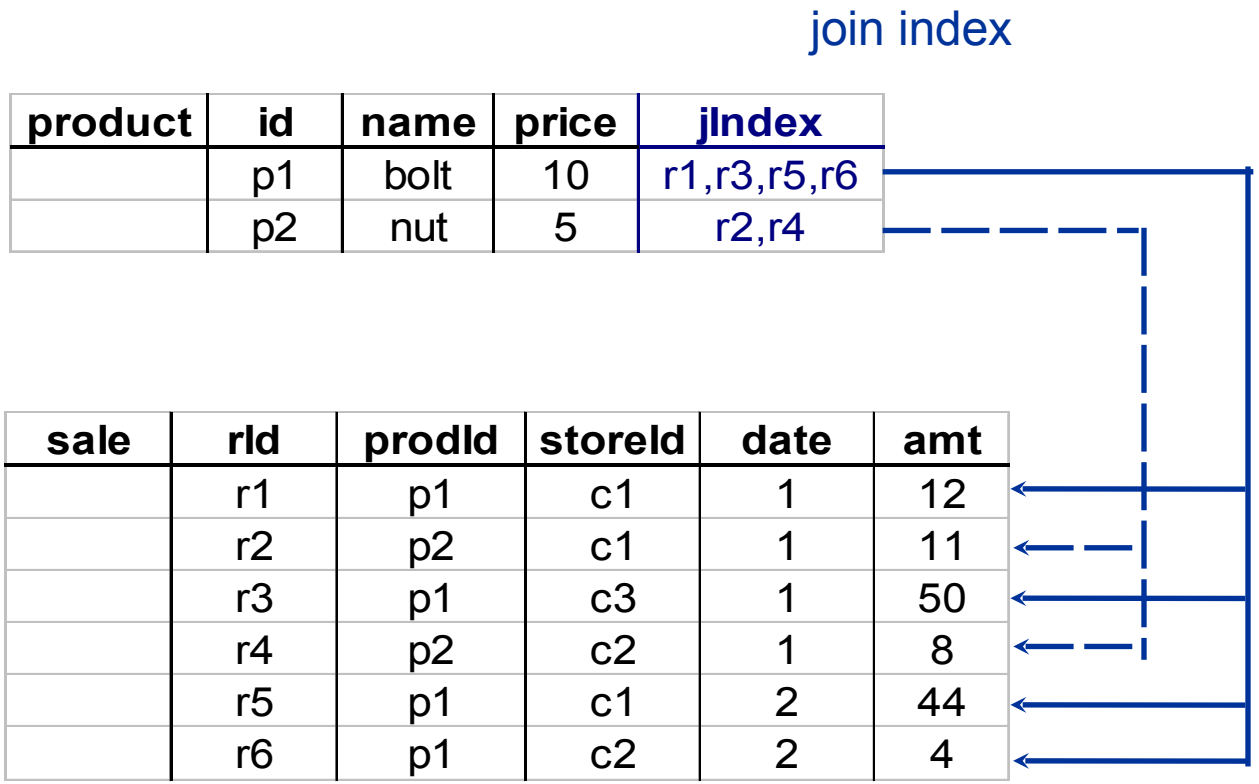
Married	Single	Divorced
1	0	0
0	1	0
0	0	1
1	0	0
1	0	0
0	1	0
1	0	0
.....	.....	.....

Y	N
0	1
1	0
0	1
1	0
1	0
0	1
0	1
.....	.....

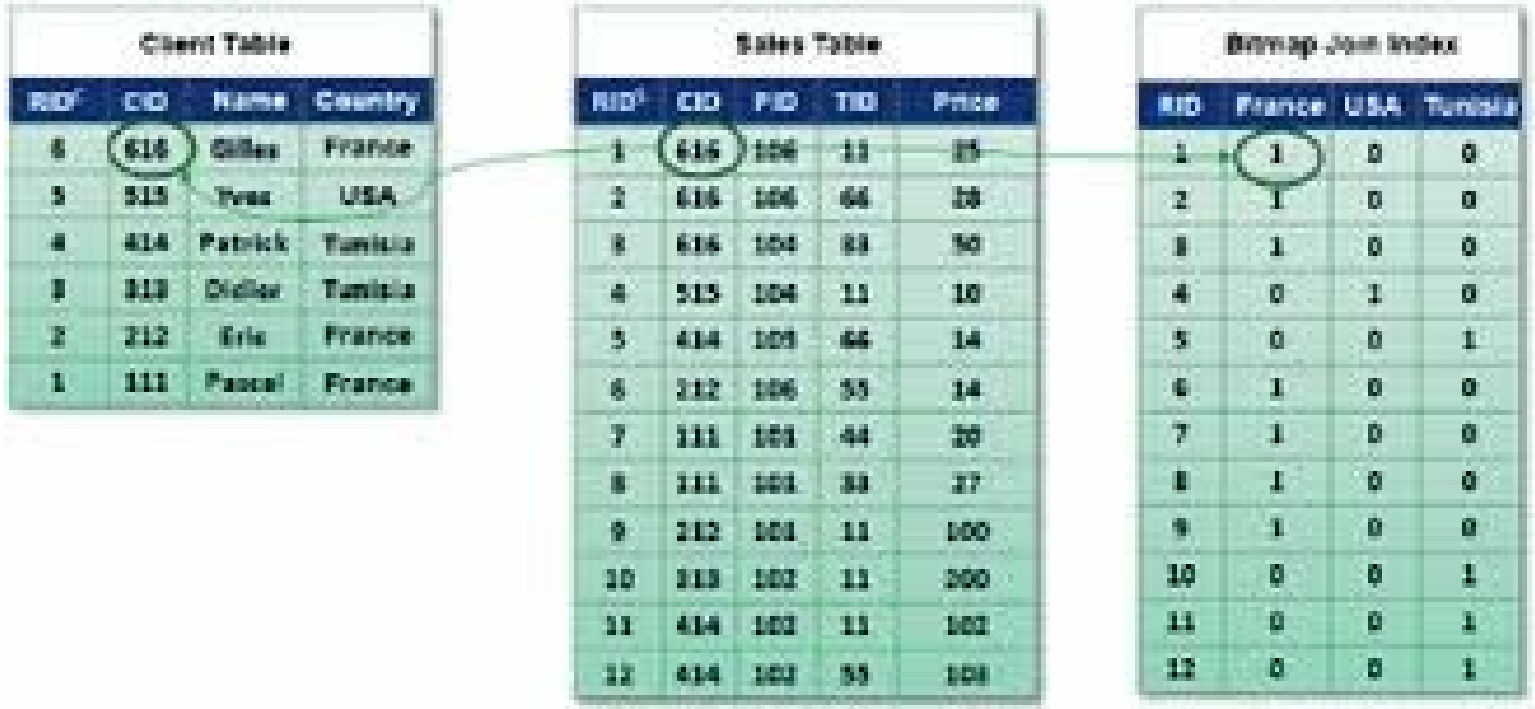
```
SELECT * FROM survey WHERE Gender='Male' AND MaritialStatus='Single' AND
HomeOwner='Y'
```



Join Index


join index
product
id
name
price
jIndex
p1
bolt
10
r1,r3,r5,r6
p2
nut
5
r2,r4
sale
rId
prodId
storeId
date
amt
r1
p1
c1
1
12
r2
p2
c1
1
11
r3
p1
c3
1
50
r4
p2
c2
1
8
r5
p1
c1
2
44
r6
p1
c2
2
4

Bitmap Join Index



Client Table

RID	CID	Name	Country
6	616	Gilles	France
5	515	Yves	USA
4	414	Patrick	Tunisia
3	313	Didier	Tunisia
2	212	Eric	France
1	111	Pascal	France

Sales Table

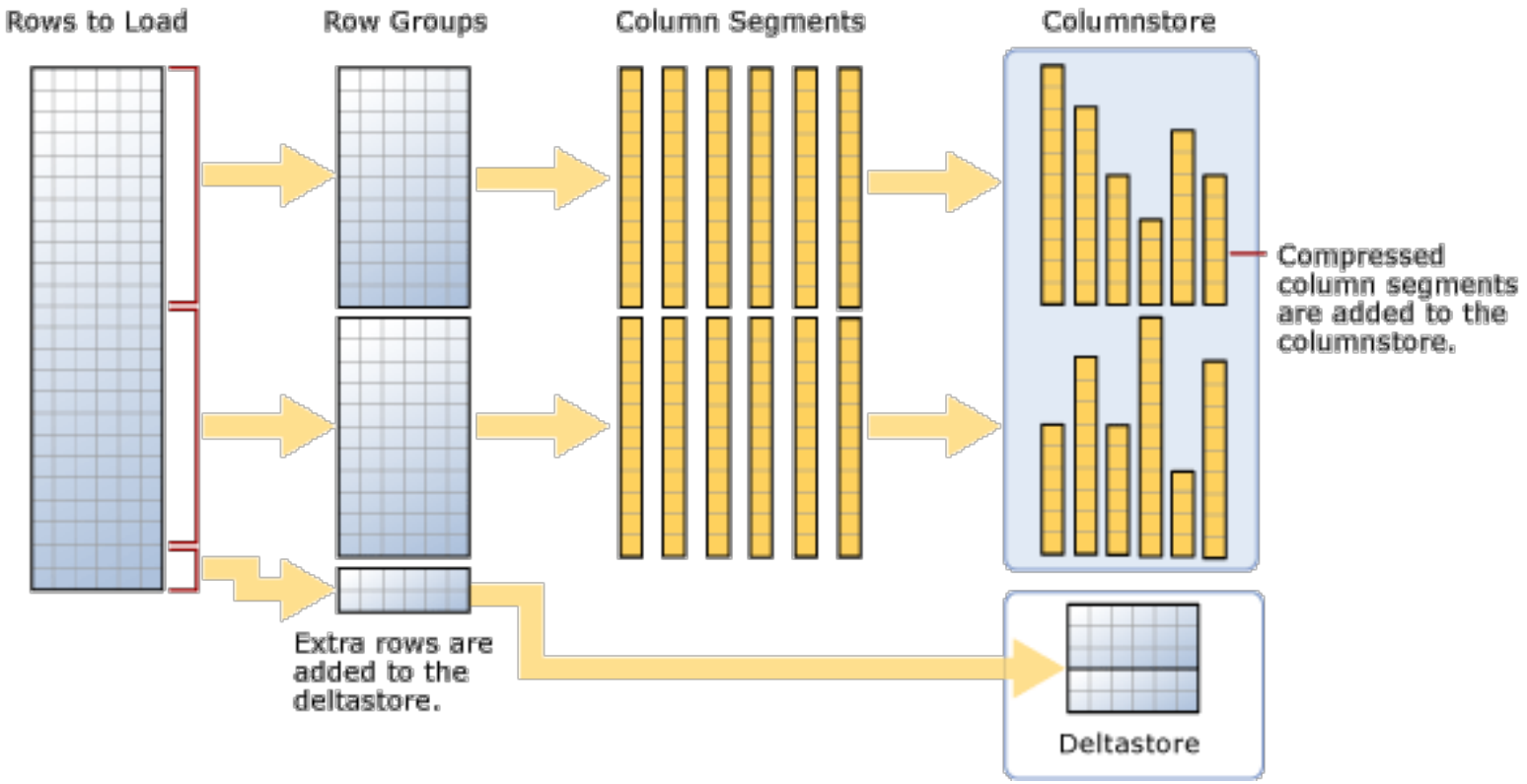
RID	CID	PID	TID	Price
1	616	106	11	85
2	616	106	66	19
3	616	104	33	50
4	515	104	11	10
5	414	103	66	14
6	212	106	55	14
7	111	101	44	20
8	111	101	33	27
9	212	101	11	100
10	313	102	11	200
11	414	102	11	102
12	414	102	55	108

Bitmap Join Index

RID	France	USA	Tunisia
1	1	0	0
2	1	0	0
3	1	0	0
4	0	1	0
5	0	0	1
6	1	0	0
7	1	0	0
8	1	0	0
9	1	0	0
10	0	0	1
11	0	0	1
12	0	0	1

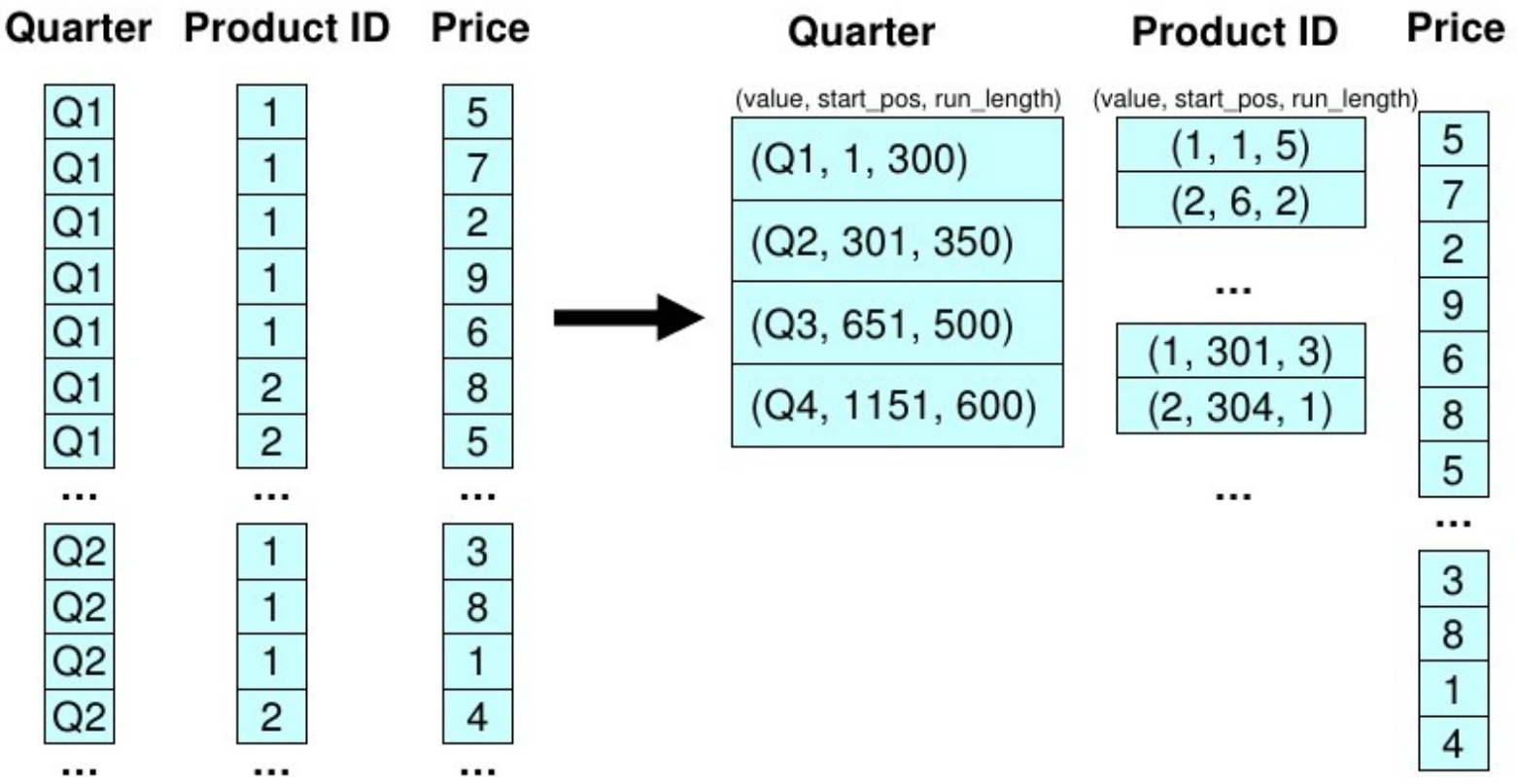
https://www.slideshare.net/gharriso/oracle-sql-high-performance-tuning

ColumnStore Index (Microsoft)



- A rowgroup is a group of rows that are compressed into columnstore format at the same time.
- The maximum number of rows per rowgroup is 1,048,576 rows.

RLE: Run Length Encoding



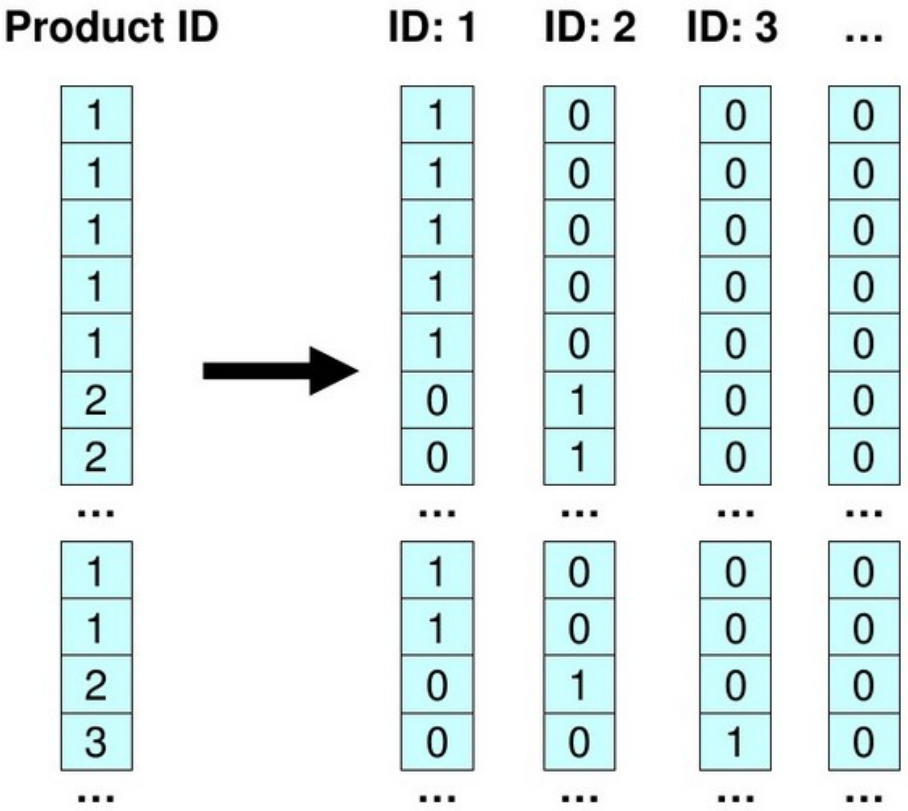
https://www.slideshare.net/abadid/vldb-2009-tutorial-on-columnstores

Bit-vector Encoding

"Integrating Compression and Execution in Column-Oriented Database Systems" Abadi et. al, SIGMOD '06

Bit-vector Encoding

- For each unique value, v, in column c, create bit-vector b
  - b[i] = 1 if c[i] = v
- Good for columns with few unique values
- Each bit-vector can be further compressed if sparse



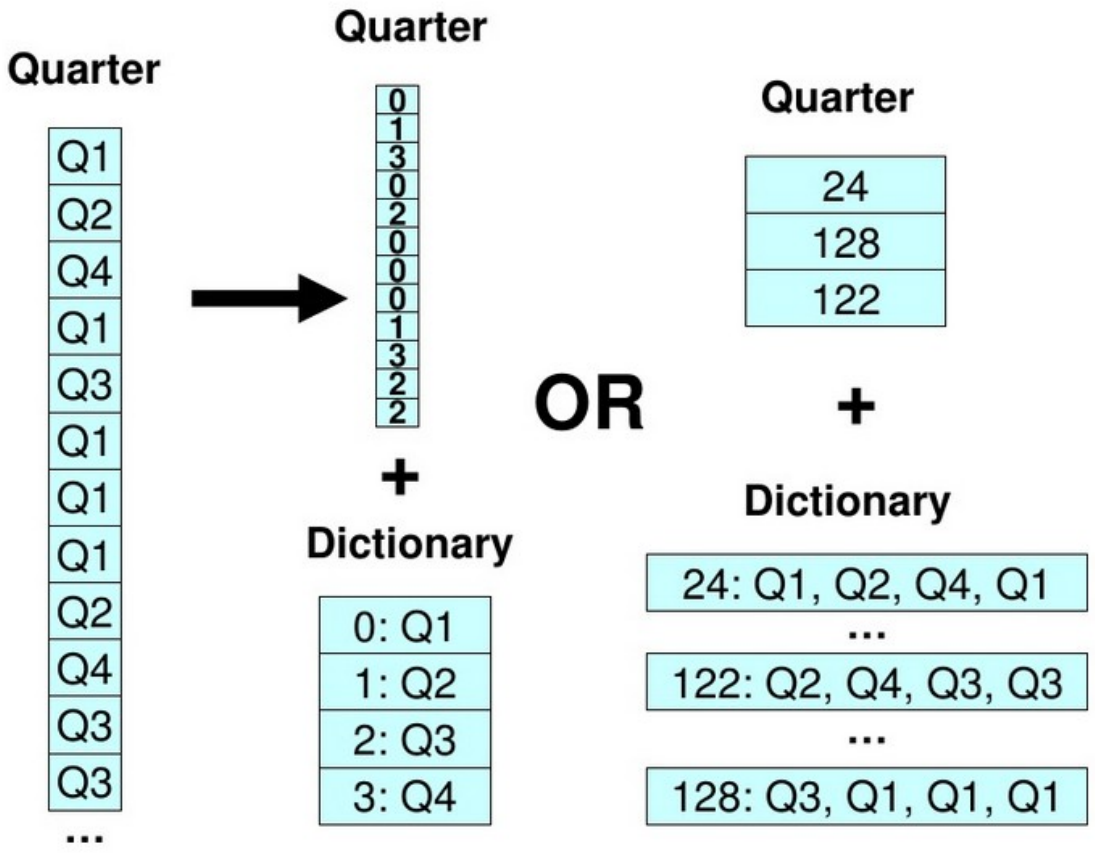
https://www.slideshare.net/abadid/vldb-2009-tutorial-on-columnstores

Dictionary Compression

 "Integrating Compression and Execution in Column-Oriented Database Systems" Abadi et. al, SIGMOD '06

Dictionary Encoding

- For each unique value create dictionary entry
- Dictionary can be per-block or per-column
- Column-stores have the advantage that dictionary entries may encode multiple values at once



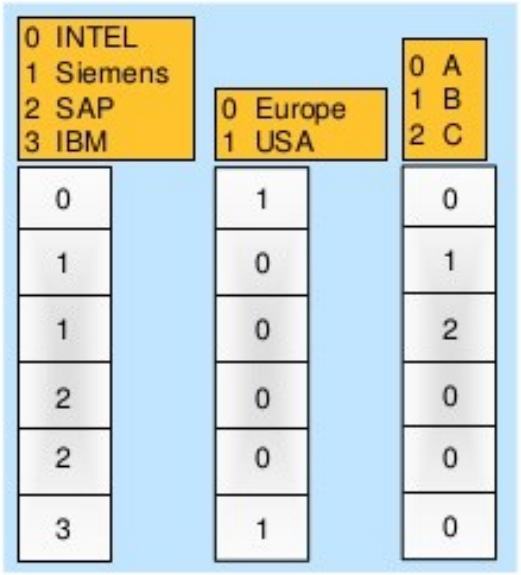
https://www.slideshare.net/abadid/vldb-2009-tutorial-on-columnstores

Dictionary Compression vs RLE

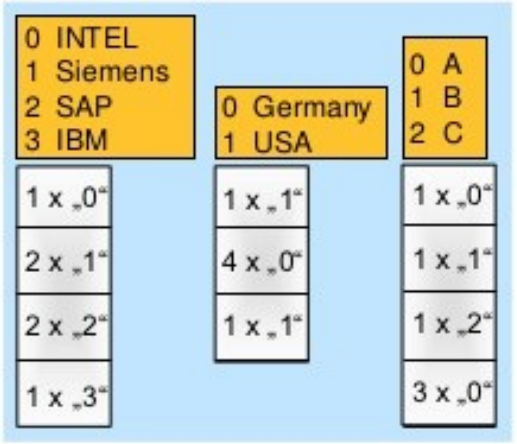
Classical DB

Company [CHAR50]	Region [CHAR30]	Group [CHAR5]
INTEL	USA	A
Siemens	Europe	B
Siemens	Europe	C
SAP	Europe	A
SAP	Europe	A
IBM	USA	A

NewDB Column Store:
Dictionary compressed



NewDB Column Store:
Run length compressed*

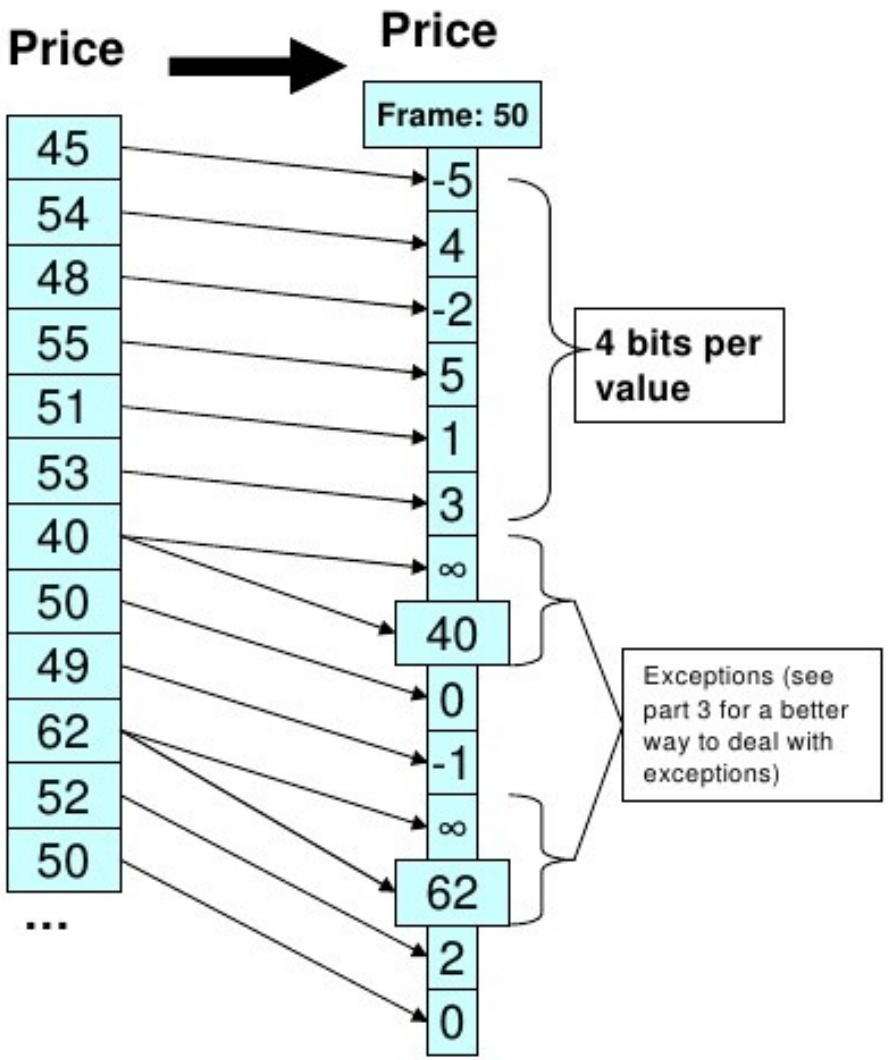


https://www.slideshare.net/abadid/vldb-2009-tutorial-on-columnstores

Frame of Reference Encoding

- Encodes values as b bit offset from chosen frame of reference
- Special escape code (e.g. all bits set to 1) indicates a difference larger than can be stored in b bits
  - After escape code, original (uncompressed) value is written

"Compressing Relations and Indexes" Goldstein, Ramakrishnan, Shaft, ICDE'98

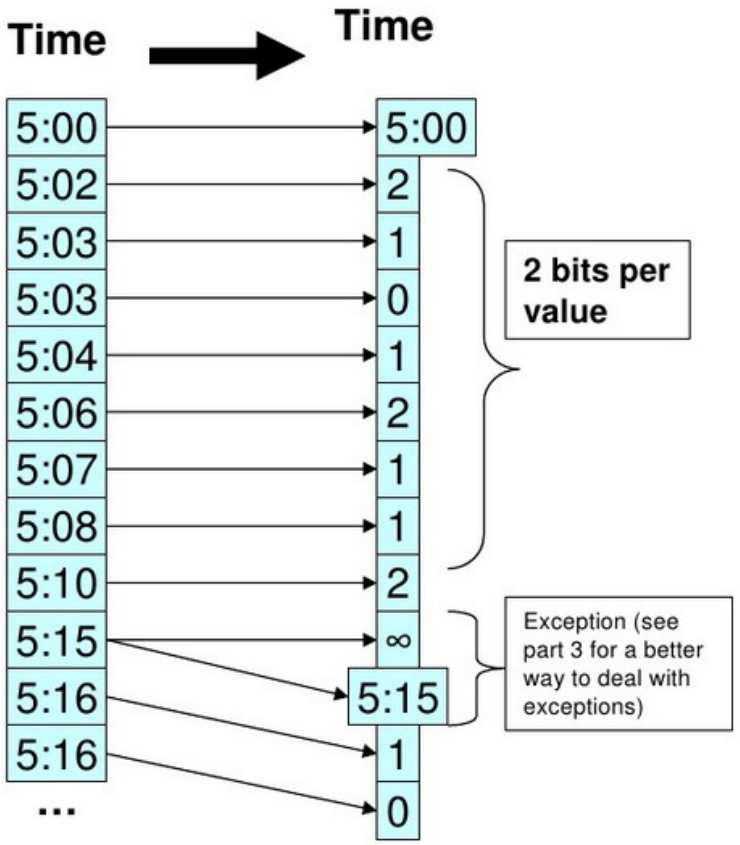


Differential Encoding

Differential Encoding

- Encodes values as b bit offset from previous value
- Special escape code (just like frame of reference encoding) indicates a difference larger than can be stored in b bits
  - After escape code, original (uncompressed) value is written
- Performs well on columns containing increasing/decreasing sequences
  - inverted lists
  - timestamps
  - object IDs
  - sorted / clustered columns

"Improved Word-Aligned Binary Compression for Text Indexing" Ahn, Moffat, TKDE'06



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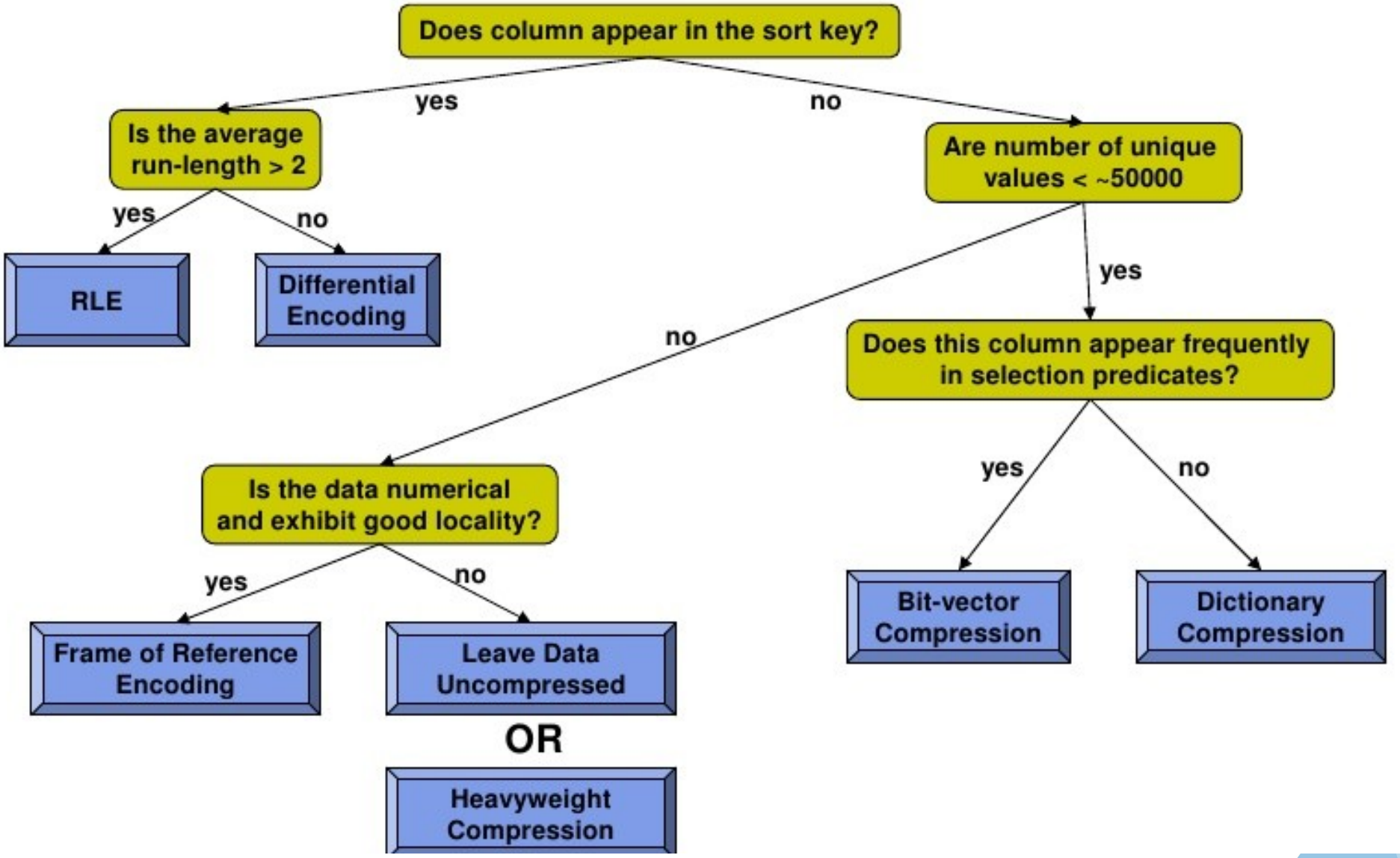
What compression scheme to use?



Source: https://www.slideshare.net/abadid/vldb-2009-tutorial-on-columnstores