Indexing notes
Index on \( R(B) \) \\

\[ \downarrow \]

Select \( B \) 
From \( R \) 
Order By \( B \) 

\[ \downarrow \]

\( B \) value \( \rightarrow \) 
Pointer to tuple

Relation \( R(A,B,C,D) \)

- Page 1
- Page 2
- Page 3
- Page \( k-1 \)
- Page \( k \)
\textbf{Index on } R(B) \\
\textbf{Relation } R(A,B,C,D) \\
\textbf{select}\ast \textbf{from } R \\\n\textbf{where } B = 5 \textbf{;} \\
\lt \textbf{assume } B \textbf{ is unique } \lt \\
\textbf{index page 1} \\
\textbf{index page 2} \\
\ldots \\
\textbf{index page } M \textbf{;} \\
M < K \textbf{;}
Index on R(B) sorted B

Second Level of Index

Relation R(A, B, C, D)

Root Level of Index
Index on \( R(A, B) \)

- \( A = 2 \) and \( B = 4 \)
- \( A = 2 \) and \( A \leq 4 \)
- \( A \geq 2 \) and \( A \leq 4 \) and \( B = 4 \)
- \( B = 4 \)

Scan between \((2, 4) - (4, 4)\)
Insert 16
Insert 29
Insert 30

Delete 42
Delete 52

Diagram with insertion and deletion operations on a data structure.
\[ n = 4 \]

- Leaf: 4 tuples (key value + pointer to tuple)
- 1 sibling index node pointer
- Internal: 4 key values
- 5 index nodes

Index on \( R(X, Y) \)

Half full:
- Leaf: 2 tuples min (4 tuples max)
- Interval: 2 nodes indexed min (5 max)

Search:

\[ X = A \]
(Select \( B \) from \( R \) where \( X = A \))

\[ Y = 45 \]
(Select \( Z \) from \( R \) where \( Y = 45 \))

\[ Y > 45 \]
Insertion Example
Insertion Example 1

Insert B80
Insert F99
Deletion Example
Deletion Example

Delete B81
Delete A5
Delete C52
Delete D98
Deletion Example

Delete c5
Deletion Example

2
Indexing duplicate values
A diagram showing points labeled as $(x, y)$, $(4, x)$, $P_1$, $P_2$, $P_3$, $P_4$, $P_5$, $P_6$, and $P_7$, with a curved line separating the points.
R-trees
QUADRESES (unbalanced)
Hesling $\rightarrow h(t) \rightarrow h(t,A) \rightarrow h^t$

Search

SELECT *
FROM P
WHERE A = 25

$h(25) \rightarrow \cdots \rightarrow 10$
Hashing

P1

P2

P3

P4