TECHNO INDIA UNIVERSITY
WESTBENGAL

Data Structures & Algorithms
(PCC-CS 301)

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Topics Covered

1. B+ tree
    1.1. Introduction
    1.2. Data searching
    1.3. Data insertion
    1.4. Data deletion
    1.5. Application

B+ Tree

- Introduction
  - B+ tree is the advanced B-tree where searching and accessing the data is faster
  - All data are stored in the leaf nodes
  - The internal node structure is different than leaf node of B+ tree
  - Internal node structure

Pi : pointers Ki : keys

  - Leaf node structure

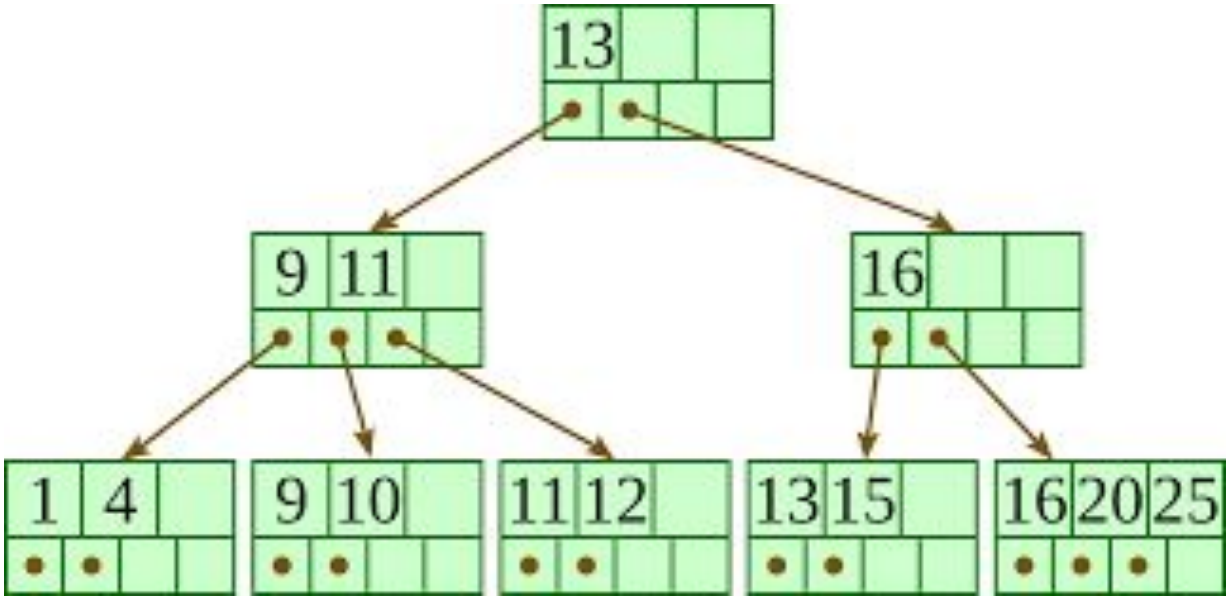
Di : data pointers Ki : keys P: next pointer

  - Arrangement of all leaf nodes (connected by links)

B+ Tree

- Example

  Order of the tree **m=4**



B+ Tree

- Data Searching

  - Data can be searched in two ways
    - Similar to B tree data searching
    - Sequentially from the leaf nodes
  - Leaf nodes provide a sorted arrangement of all data
  - Searching time is $O(\log_m n)$, m is the order of tree and n is the total number of nodes
  - In some cases, data searching is more faster than B tree as B+ tree is more balanced than B tree

B+ Tree

- Data Insertion

  - Data are stored in the leaf node

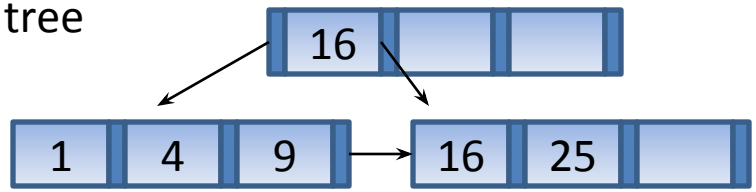
  - If the target leaf node is full
    - Split the node into two halves
    - The median data will be promoted up as a data of new node
    - If the upper node is also full, perform the same process

  - Otherwise insert the new data in the target location

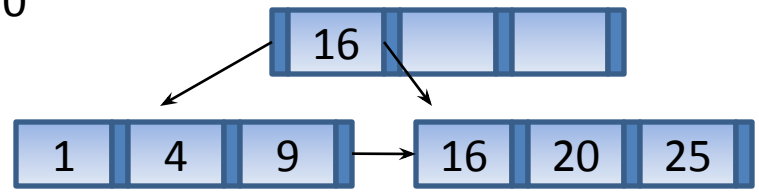
B+ Tree

- Data Insertion (degree = 4)

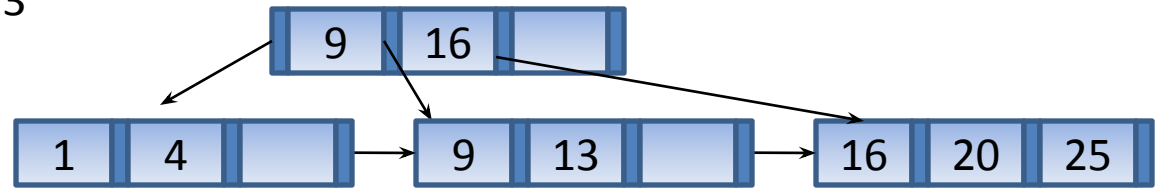
Initial B+ tree



Insert: 20



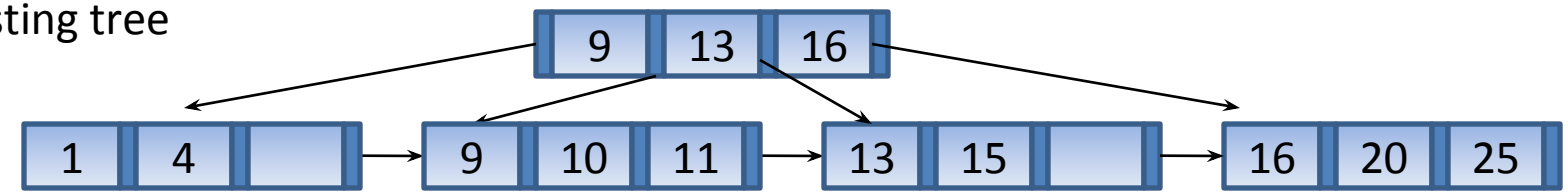
Insert: 13



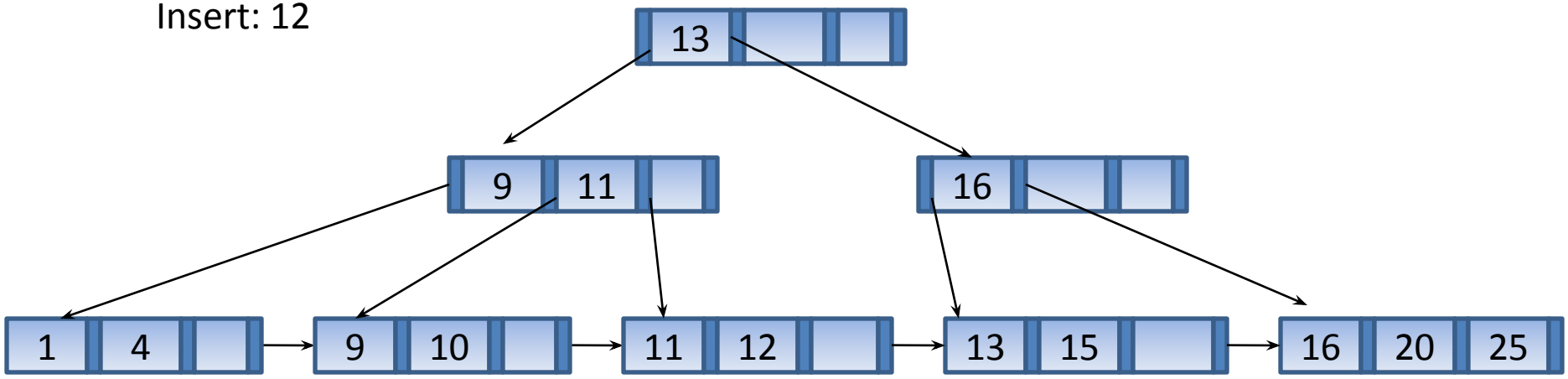
B+ Tree

- Data Insertion (degree = 4)

Existing tree



Insert: 12

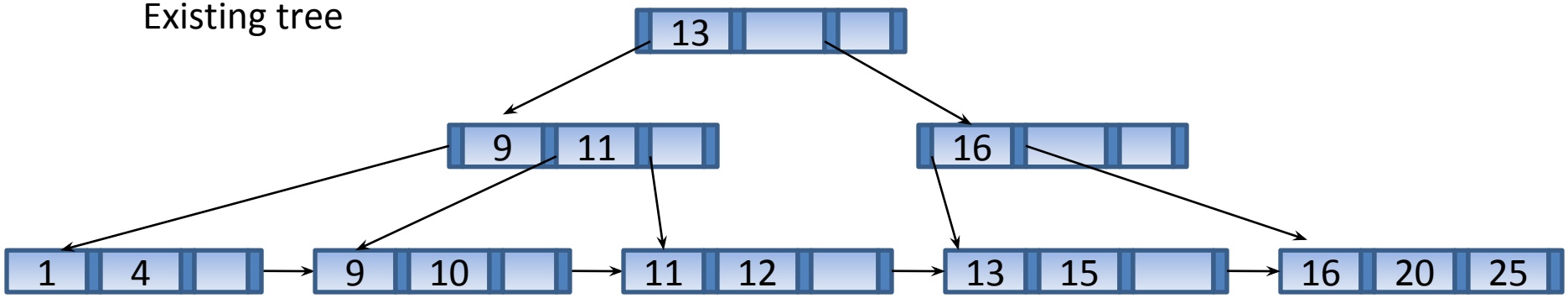


B+ Tree

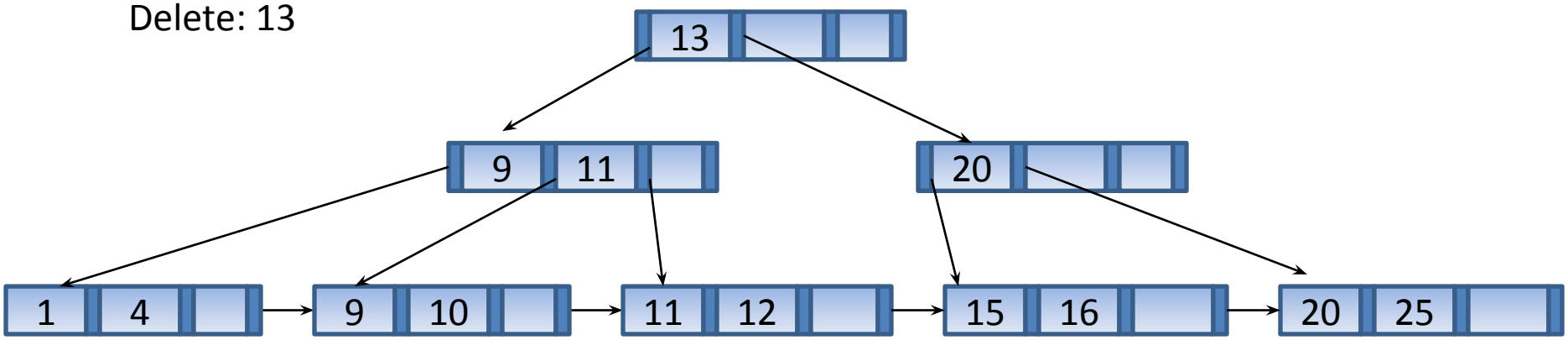
- Data Deletion (degree = 4)

  Data will be deleted from the leaf

Existing tree



Delete: 13



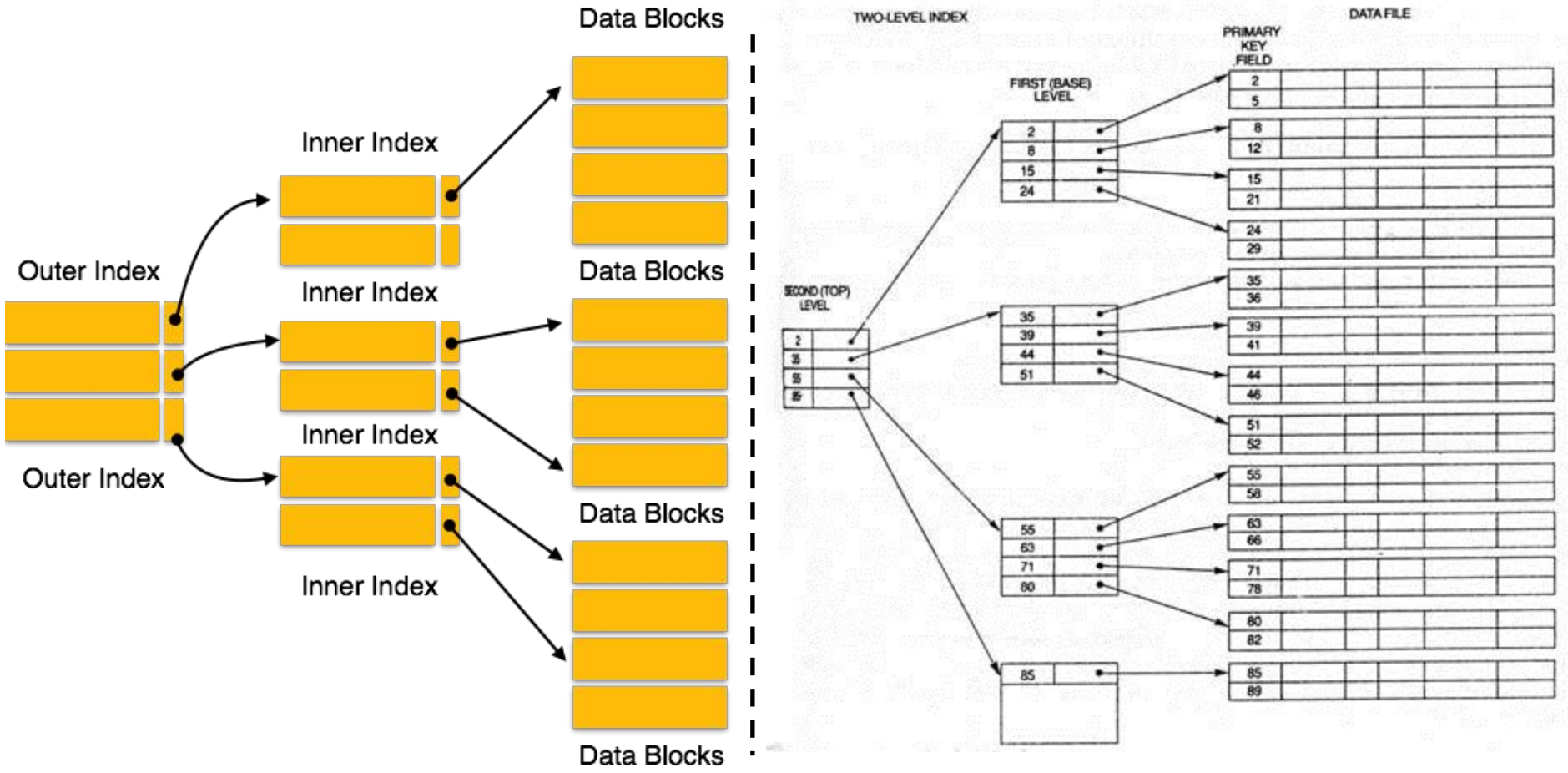
B+ Tree

- Application

  - Used for data storage in secondary storage memory
  - Few Databases, Hard-disk, CD uses B+ tree for data storage
  - Popular due to its efficient data accessing
  - For implementing multi-level file indexing B+ tree is used
  - Used in DBMS, OS for data indexing

B+ Tree

- Application (in multi-level indexing)



Queries?

Practice Problem

1. Consider the following data that need to be inserted in a B+ tree having degree 5

{ 25, 40, 15, 10, 6, 28, 32, 35, 50, 5, 12, 8, 10, 38, 3, 45, 23, 42, 1, 50, 22, 17 }

2. Delete the following set of data from the previously maintained B+ tree data structure

{ 25, 6, 50, 5, 3, 45, 17 }