**1. R-Tree (Region-Tree)**

**Definition:**

* A tree data structure used for spatial indexing in multidimensional space.
* Stores **d-dimensional** intervals (rectangles, squares, etc.) for indexing.

**Structure:**

* **Leaf nodes**: Contain tuples with **(I, tid)**, where I is the region (bounding box), and tid is the tuple identifier.
* **Inner nodes**: Contain entries (I, cp), where I is the minimum bounding box covering all child nodes, and cp is the pointer to the child node.

**Specialties:**

* **Supports multidimensional range queries** efficiently.
* Handles spatial objects (e.g., geographic data, 3D models).
* **Overlapping regions** may require multiple branches to be searched.
* **Insertion Strategy**:
  + Find an interval that does not need to be extended.
  + Otherwise, extend the interval that requires the least increase.
* **Variants:**
  + **R+-Tree**: Avoids overlapping regions by **splitting objects** into multiple nodes (can cause node fragmentation).
  + *R-Tree*\*: Minimizes overlap but **allows some** to improve efficiency.
  + **R\*a-Tree**: Used for **OLAP queries**, stores **aggregated values** like SUM, MAX, COUNT.

**Use Case:**

* **Geographic databases** (e.g., GIS, navigation systems).
* **Spatial queries**: Find all points within a given area (e.g., "Find all warehouses within 50 km").