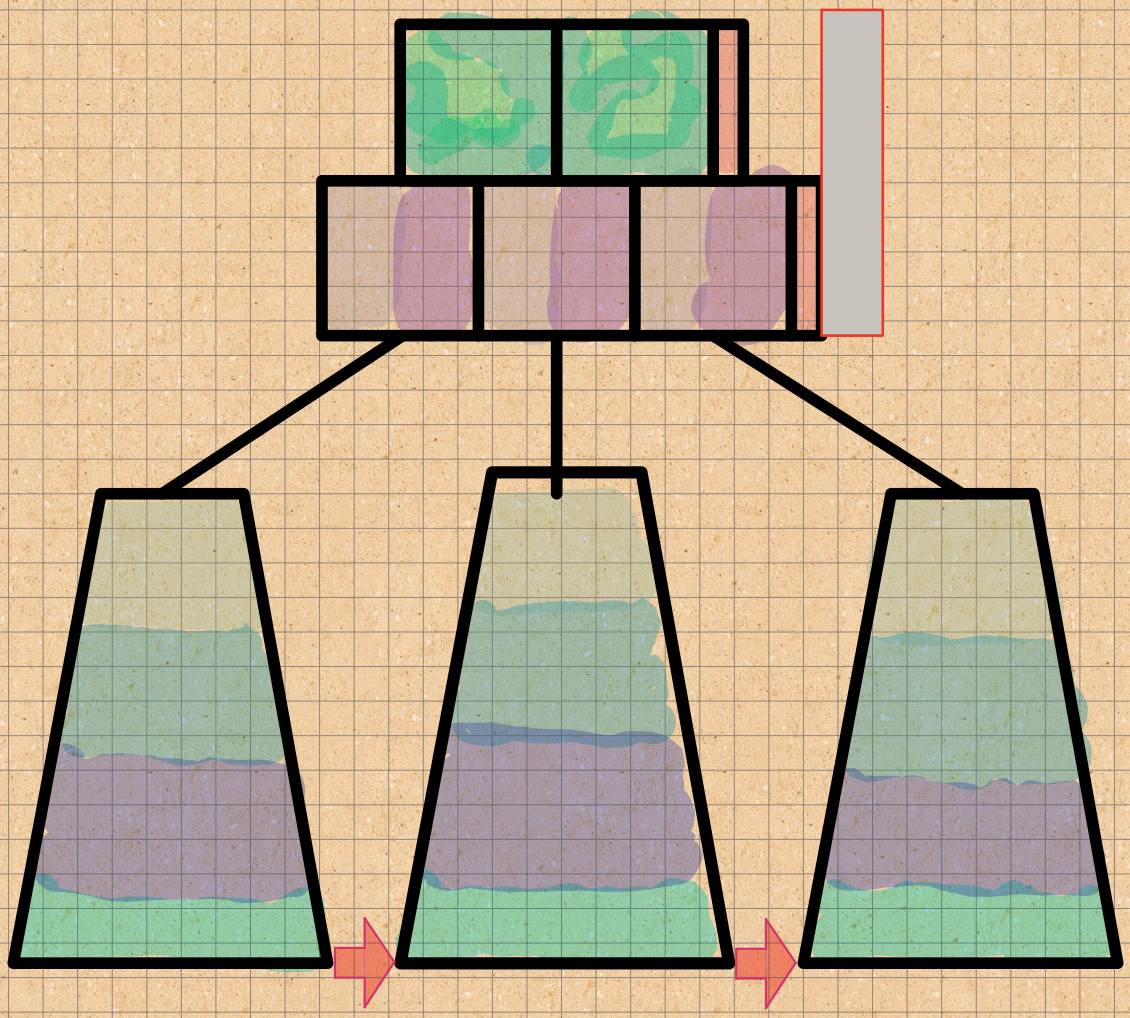
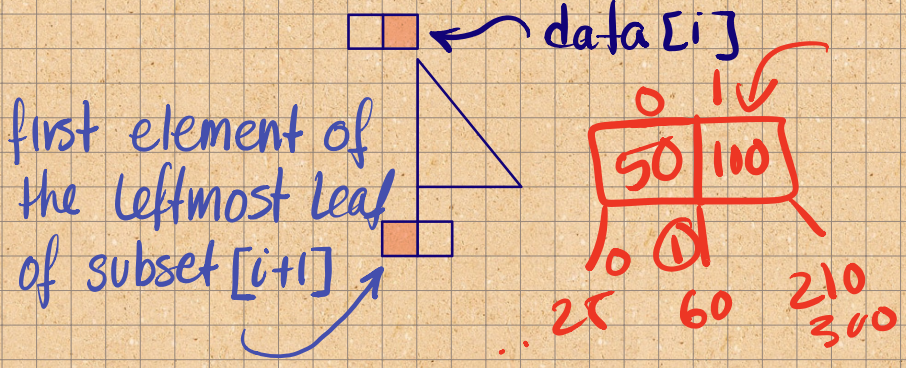
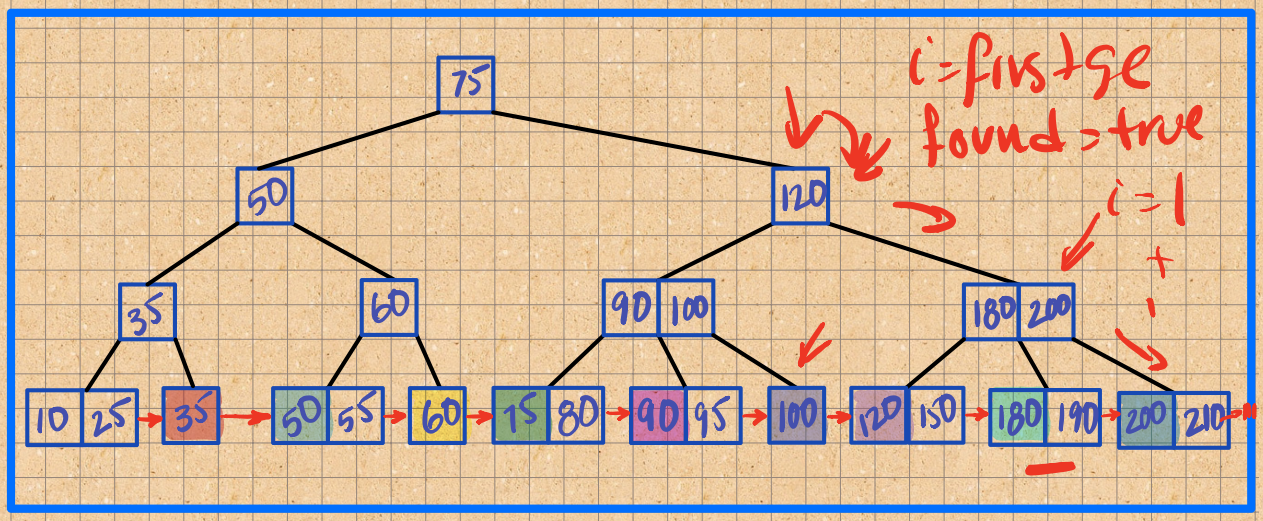


B Plus Tree

- All keys are present at the leaf level.
- A next pointer links each leaf node to the next and leaf nodes only
- Each entry in data[i] is equal to the first element of the leftmost leaf of subset [i+1]





- The inner nodes serve as bread crumbs to find the actual node in the leaves

General approach for b+trees to seek and process entries

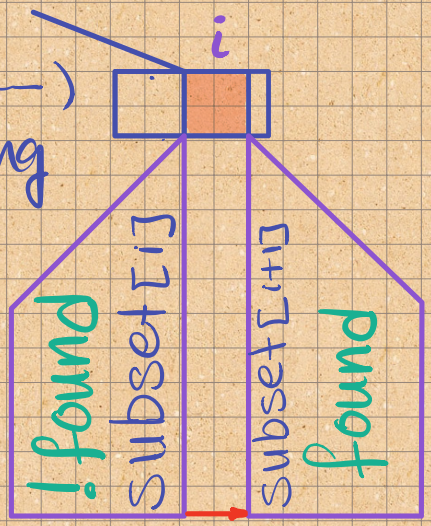
index = first_ge(...
found = ...

	found ✓	!found	
Leaf	found it	It's not there	inner nodes are bread crumbs:
!Leaf	subset[i+1] → recursive fix things	subset[i] → recursive fix things	

i = first_ge(—)

the key you are looking for is

in subset[i+1]
  if same key is in this inner node
else
  it could be in subset[i]

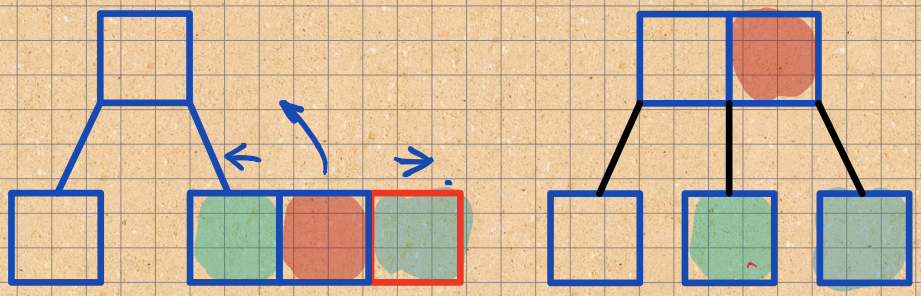


for loose_insert:

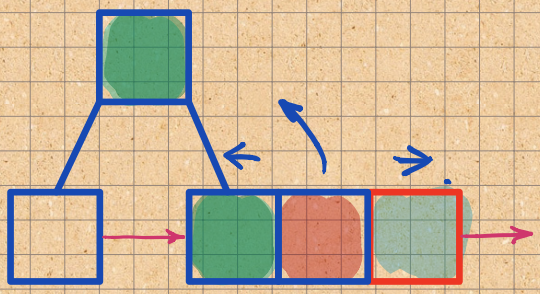
	found	!found	first_ge returns i found is true if i<dc & data[i] == entry
Leaf	it's a duplicate	insert key here @ pos i	
!Leaf	subset[i+1] → loose_insert fix-excess	subset[i] → loose_insert fix-excess	

fix_excess

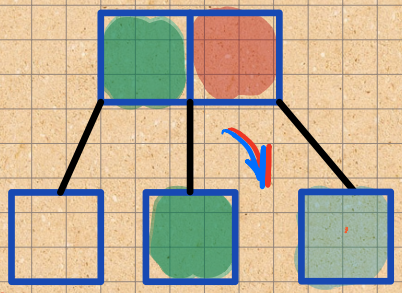
btree



b+tree

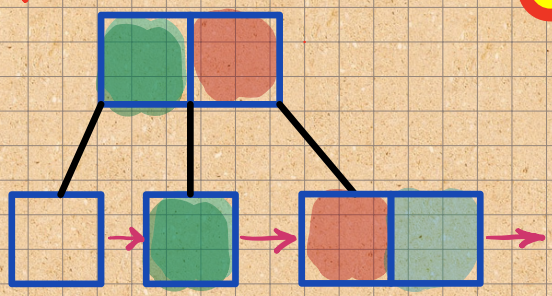


b+tree inner nodes behave exaclty as btree nodes do



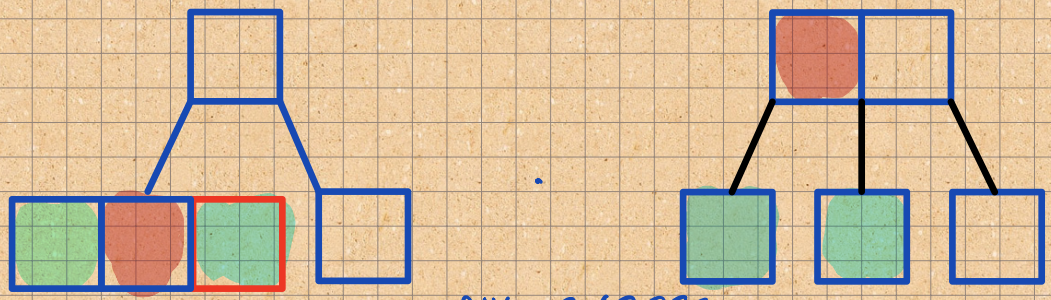
- Split and move half to i+1
  Move middle up to pos i

If a leaf:



- If leaf:
  insert middle value to pos 0 of i+1
  - connect the links

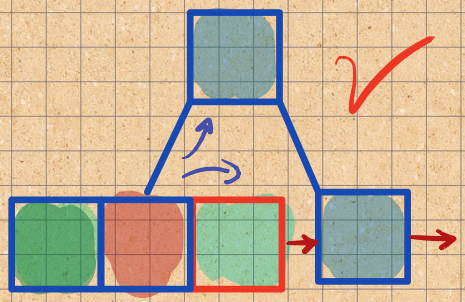
btree



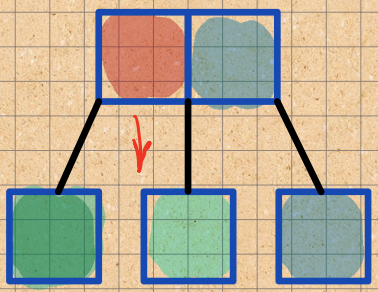
fix excess

b+tree

b+tree inner nodes behave exactly as btree nodes do

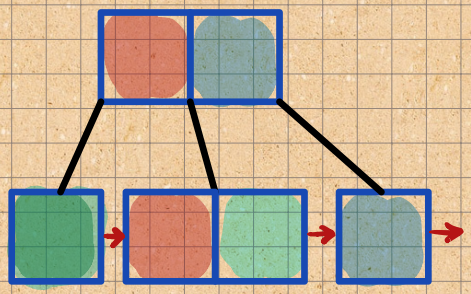


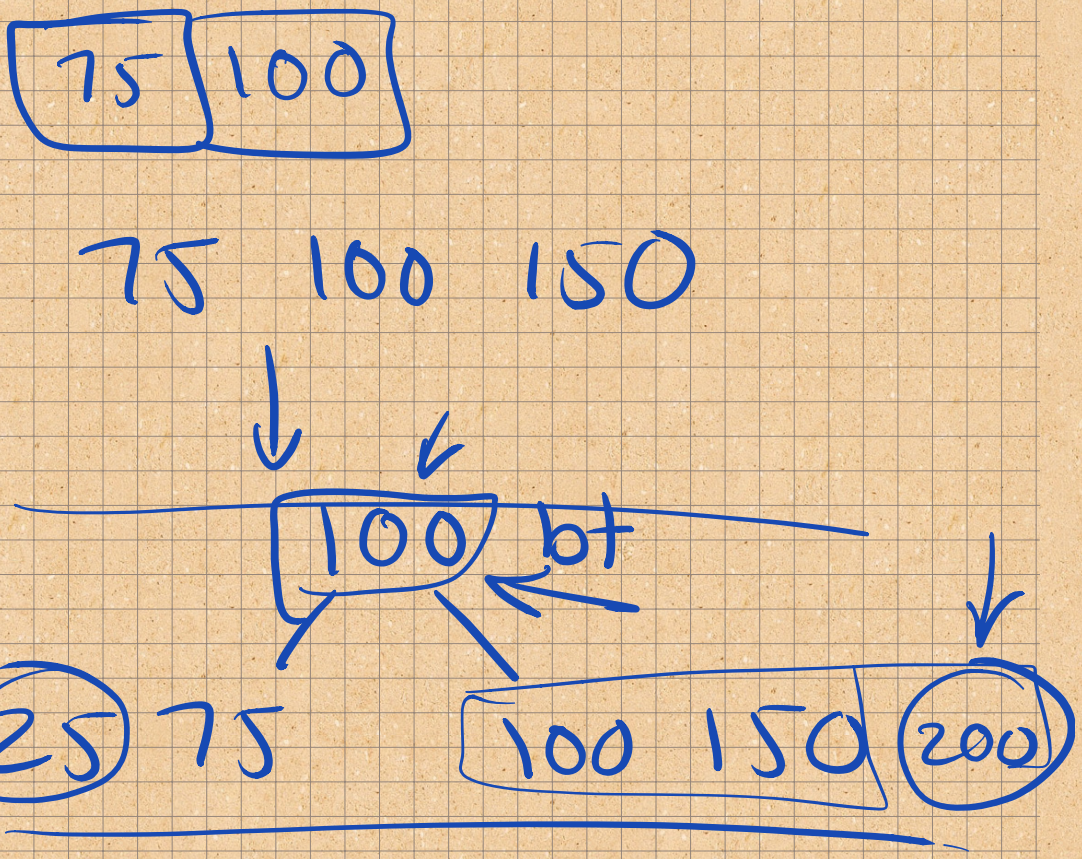
split & move middle value to position i in parent



if a leaf:
insert middle value at position 0 in i+1

fix links:
a standard insert_after



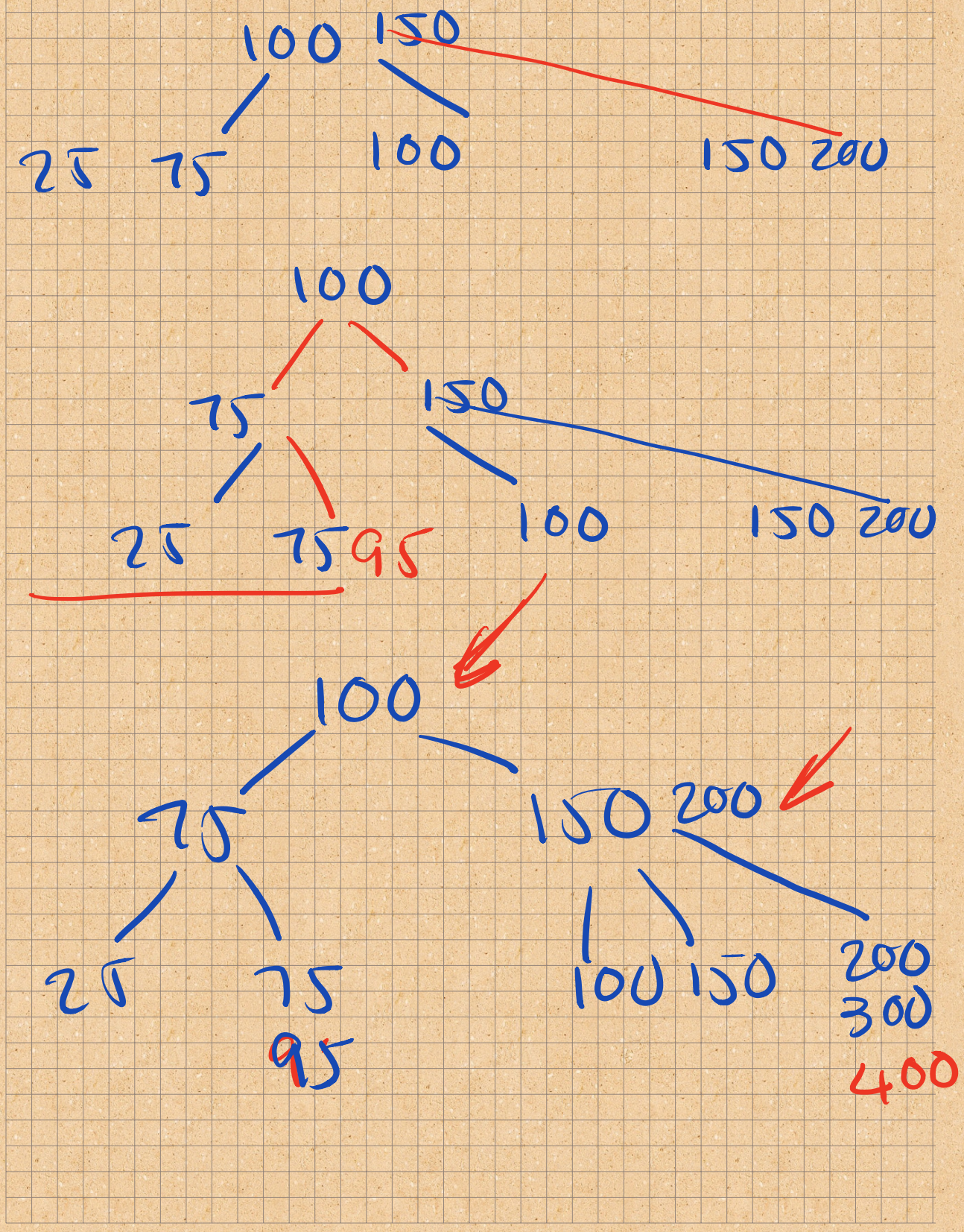


bt.insert(200)

i = fge( )

subset[1].insert

f.e.


100 150
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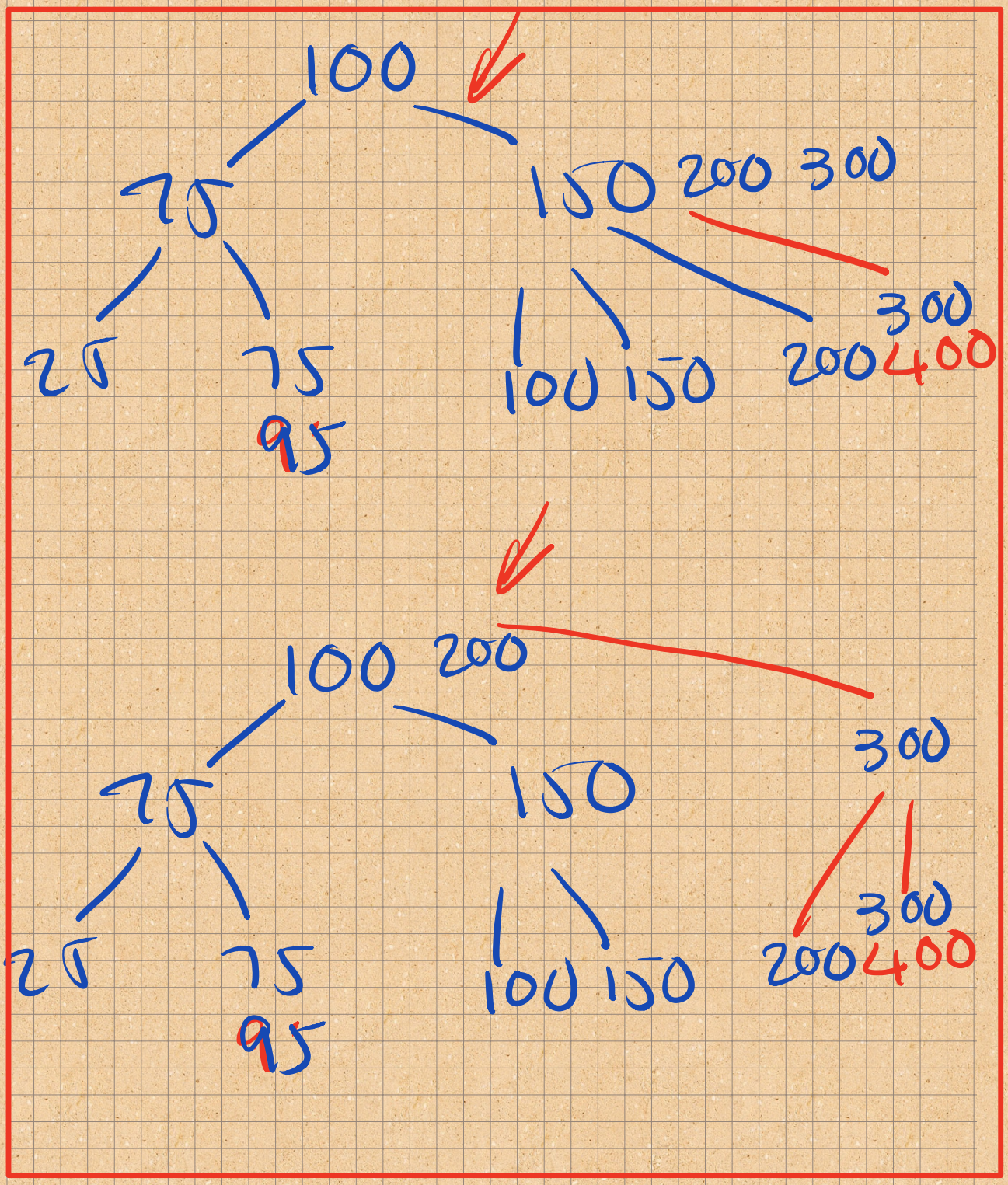
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200
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loose_remove

may cause this node with less items than minimum

once loose_remove returns, the caller may need to call fix_shortage

- data to be removed resides in the leaf nodes
  - once the data is removed any "sister data" elements (breadcrums) must be removed and be replaced with the smallest data item in subset ith subtree
  - poorman's version:
    leaving the breadcrum data items on the tree will, in time, clutter the b+ tree, but will not interfere with the proper operations of the b+ tree - I hope.

fix_shortage:

fix-shortage is called on the child with less than minimum number of data items, by the parent node.

4 Scenarios:

1. child i+1 has more than min
   borrow from right:
   transfer / rotate left

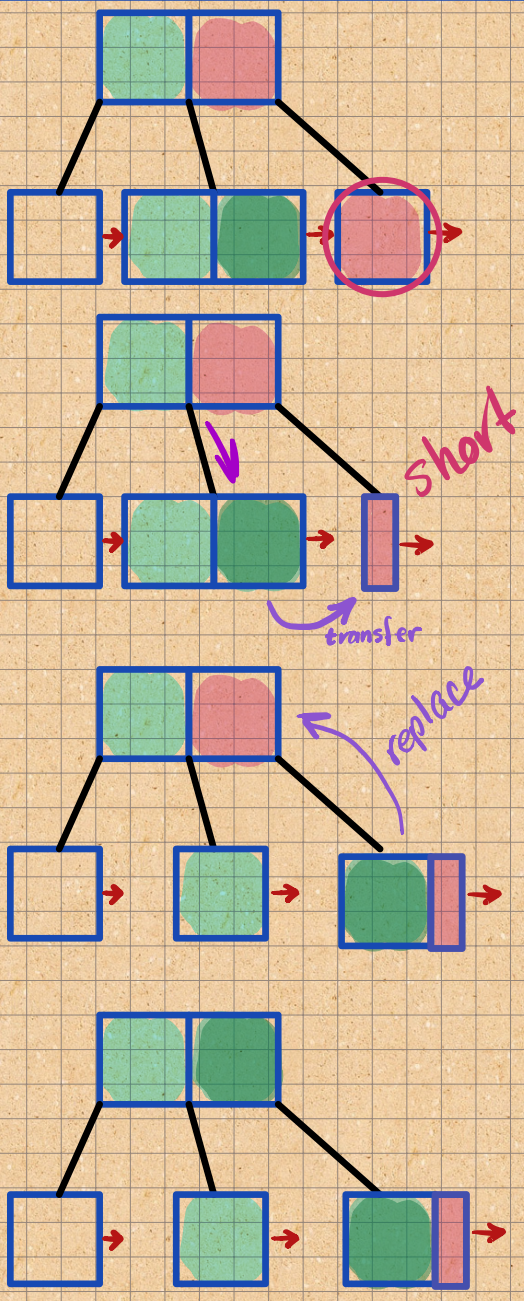
2. child i-1 has more than min
   borrow from left
   transfer / rotate right

3. there is a left sibling
   merge with previous:
   merge(i-1)

4. there has to be a right sibling
   merge with next:
   merge(i)

1. transfer right (i-1)

tell the subset to short's left (i-1), to transfer right to short

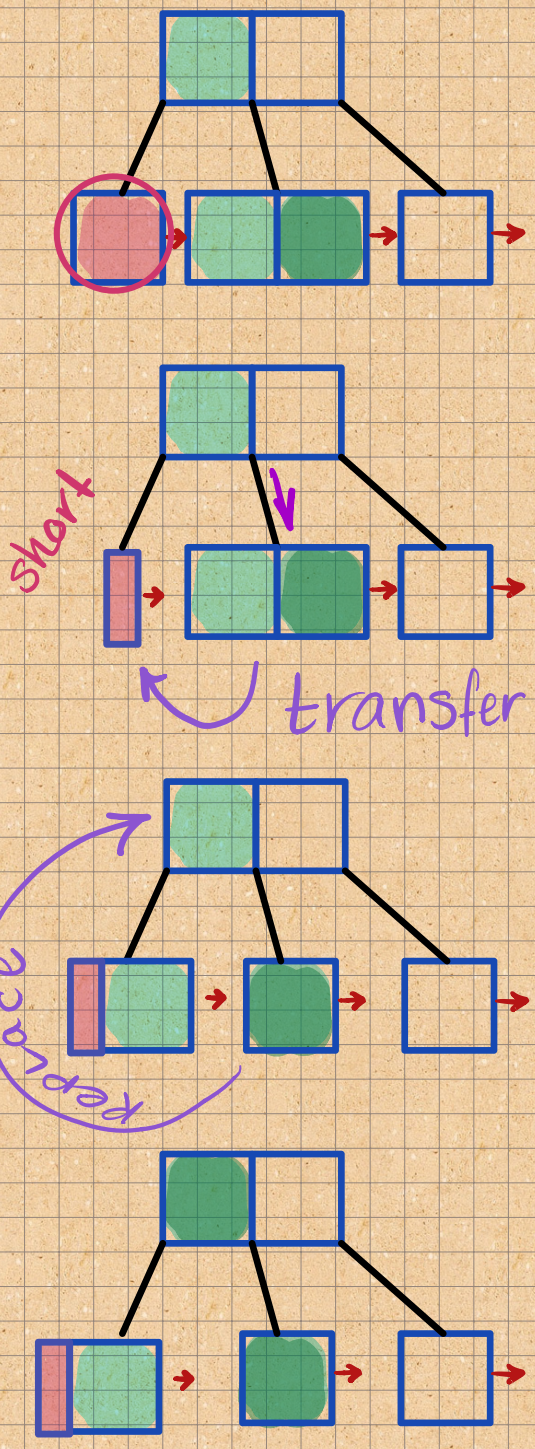


Leaves only

- transfer the last data item from [i-1]→data to [i]→data
- replace data[i] with this data item.

2. transfer Left (i+1)

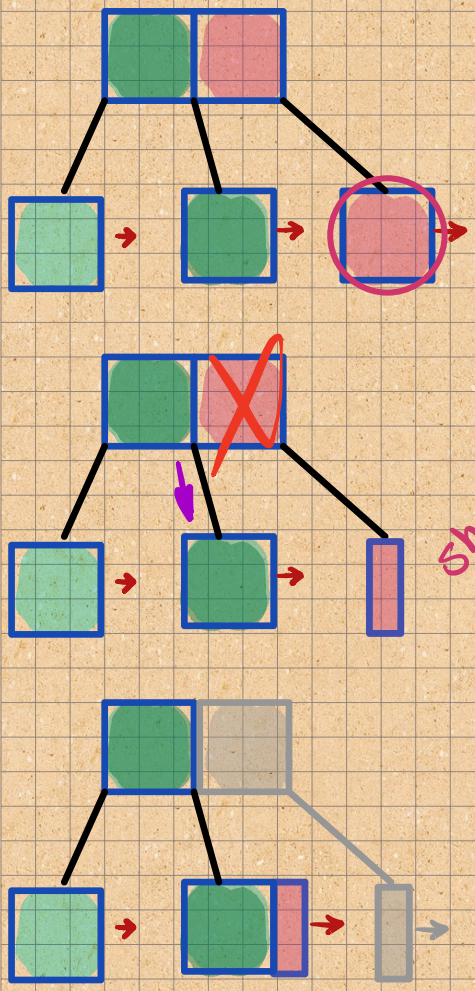
tell the subset to the left of short (i+1) to transfer left - to short



Leaves only

- Transfer
  [i+1] → data[Ø]
  to the end of
  [i] → data
- replace data[i]
  with
  [i+1] → data[Ø]

3. merge_with_next(i-1)



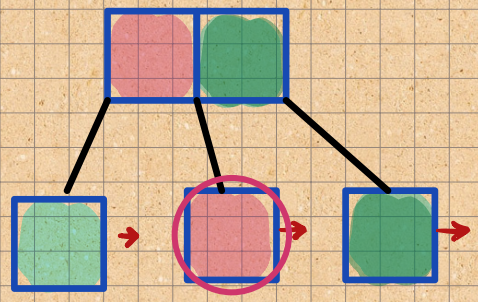
i>0: tell the subset to the left of short (i-1), to merge with his next subset - short

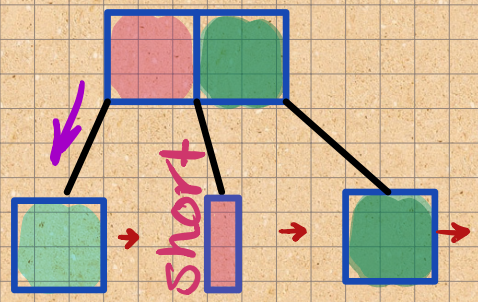
for leaves:

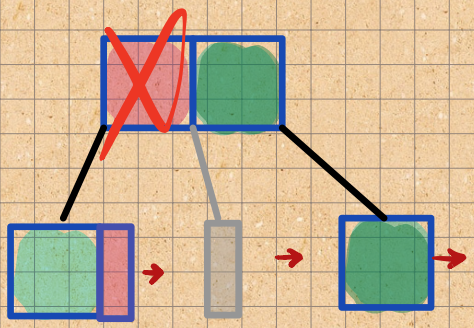
delete data[i], but do not attach to subset[i] → data

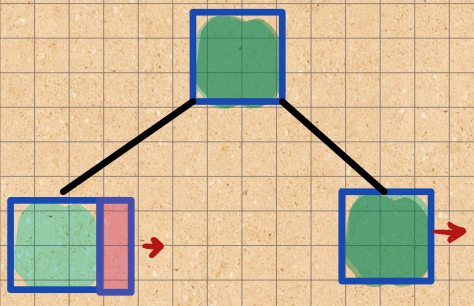
then merge data[i+1] with data[i]

4. merge_with_next(i)









i < data_count-1 :
merge the short subset with his next sibling

delete data[i], but
do not attach to
subset[i]->data

merge
subset[i+1]->data
with subset[i]->data

copy_tree

- A solid copy_tree is necessary for a reliable Big Three
- Challenge: How to connect the next pointers on the leaves
- copy_tree function takes two arguments:
  - a btree node : Other
  - a btree pointer: (by reference) "last_leaf"
- copy_list algorithm

copy the other's data over
if the other guy is not a leaf
  for every child of the other
    Copy other's child as my own

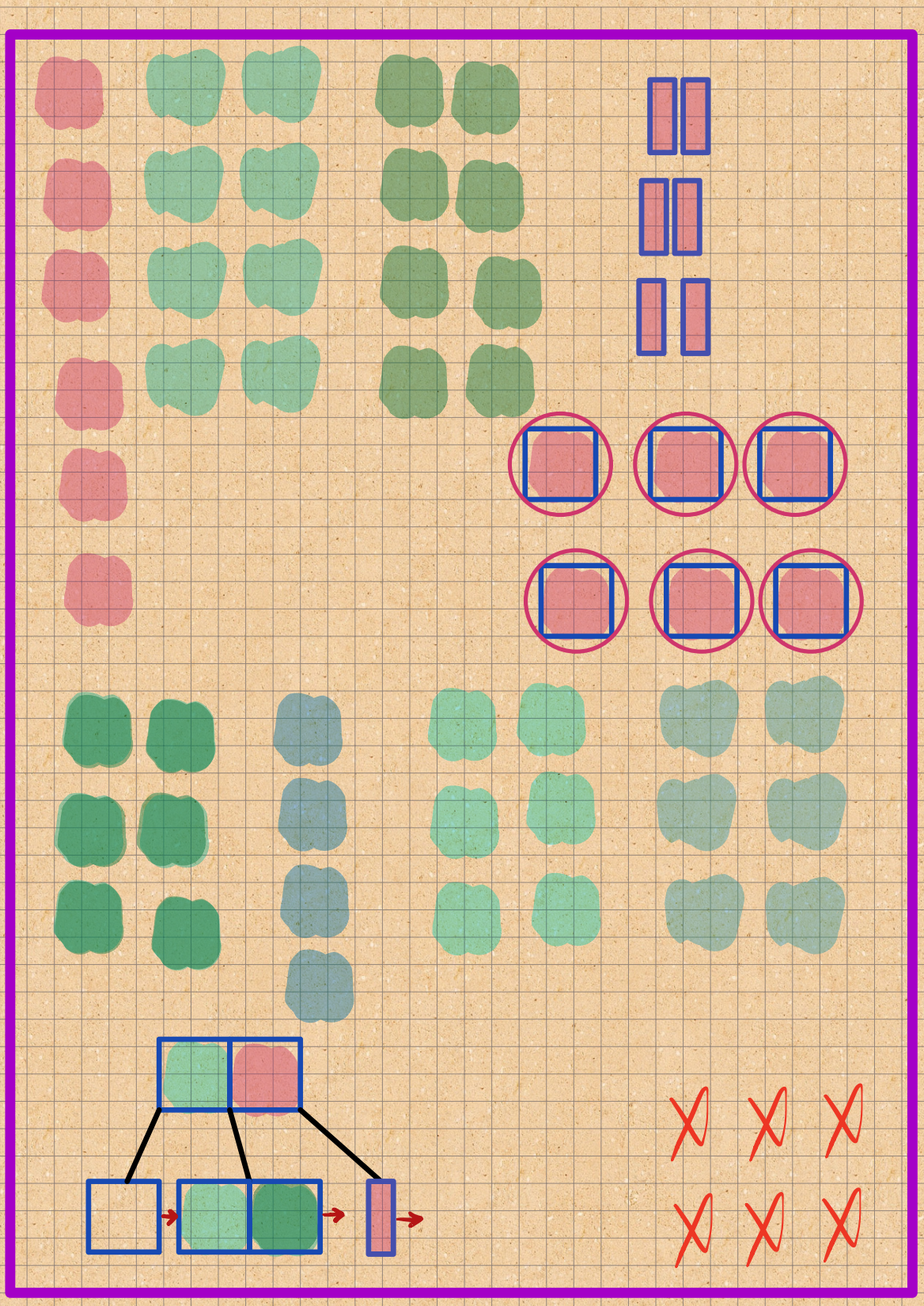
else, if other is a leaf:
  point last_leaf's next to this node if last_leaf is not null
  set last_leaf to this node.

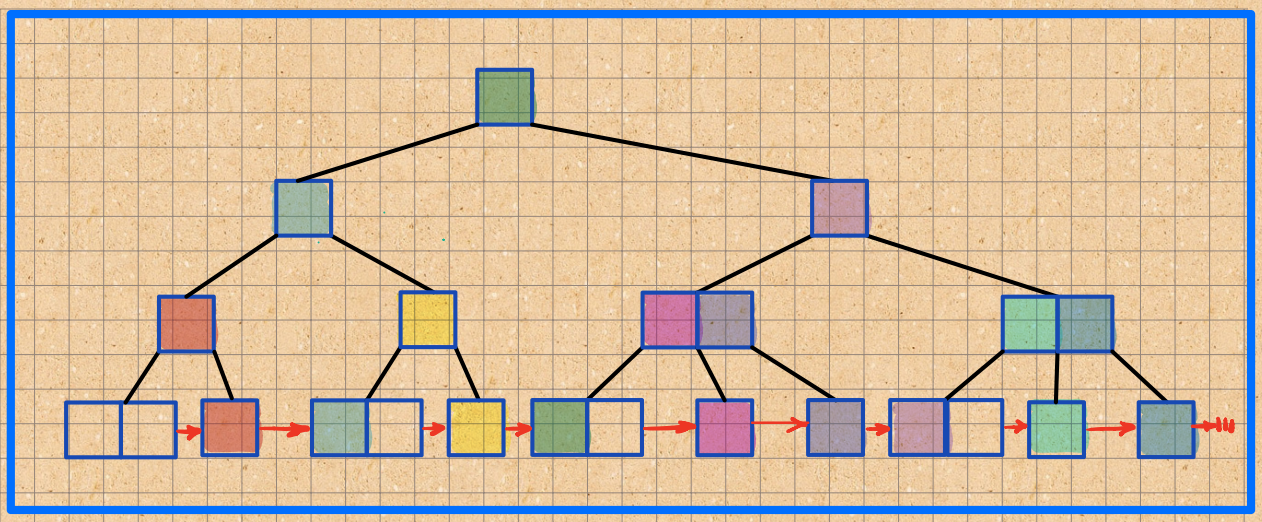
Iterators

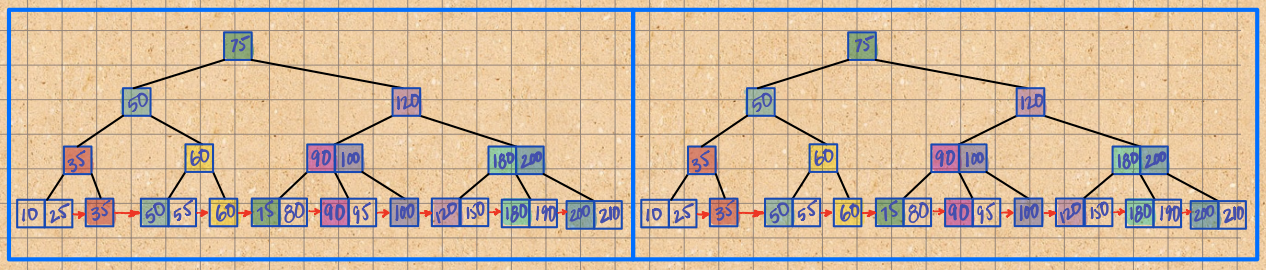
A pointer for the nodes
and
an int for the data index in data array

++ : increment the int until it reaches dc-1 then set it to zero & advance the pointer

* : returns T at index of the node being pointed to by pointer



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