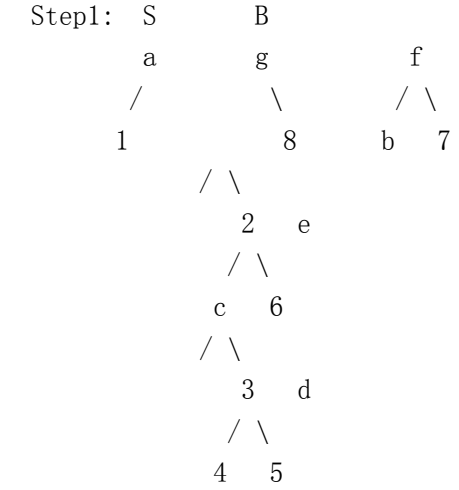
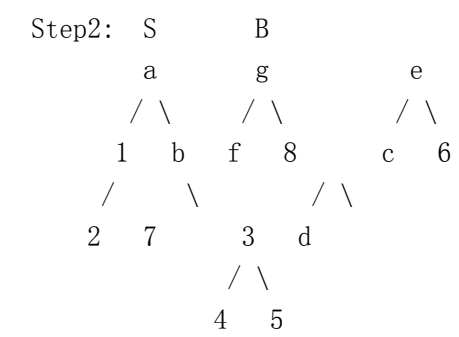
1.

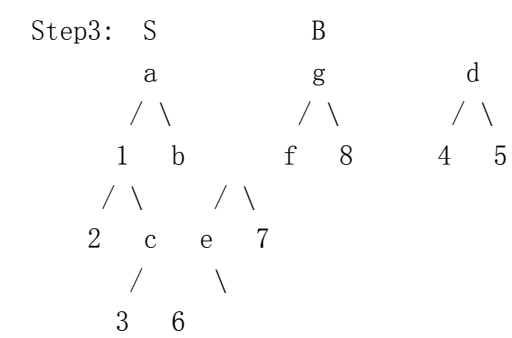
Step1:



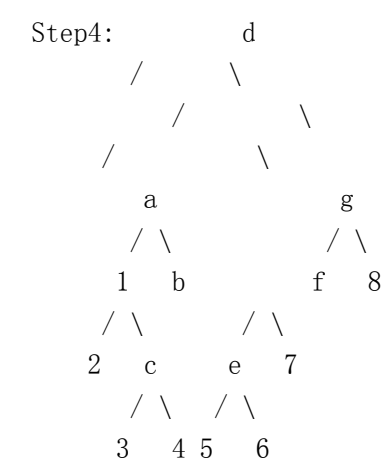
Step2:



Step3:



Step4:

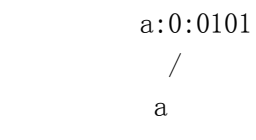


2.

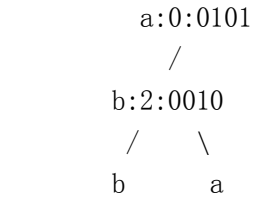
It is hard to draw the backward pointers using ASCII characters. So I will put a label on every node, and use that to set up the backward pointer. And we follow the left branch if the bit is 0.

So a node looks like: <label>:<bitnumber>:<key>.

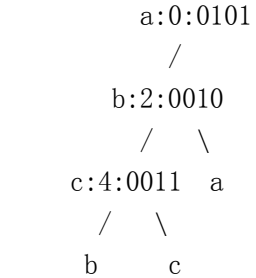
After inserting 0101:



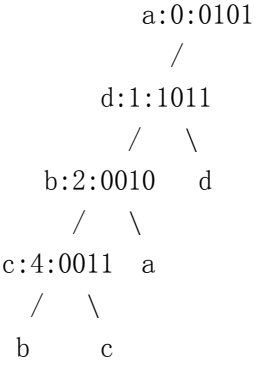
After inserting 0010:



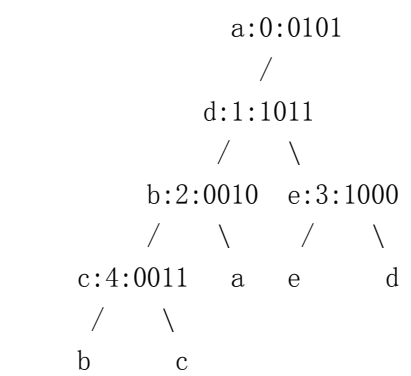
After inserting 0011:



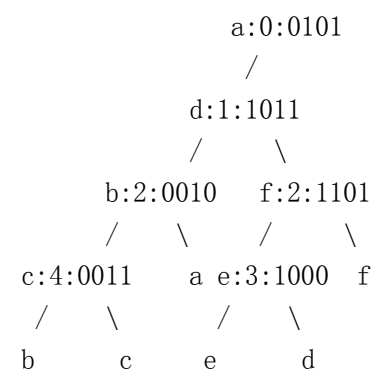
After inserting 1011:



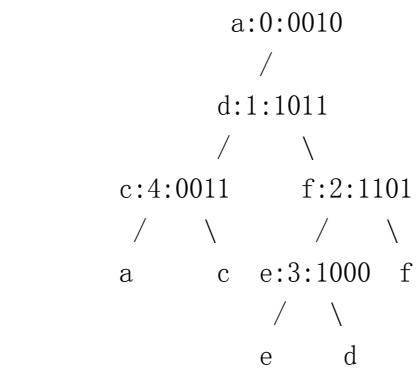
After inserting 1000:



After inserting 1101:

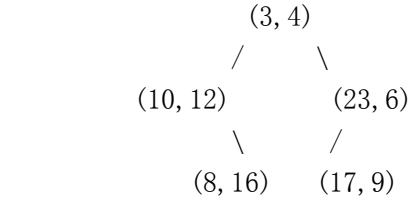


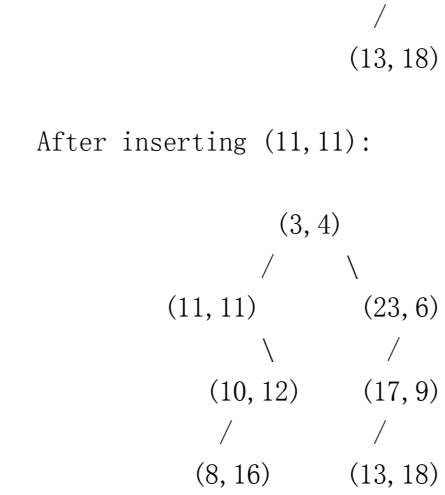
After deleting 0101:



3.

Initial tree:





After inserting (11,11):

4. Segment tree

(a)
starting from the root,
if node range is covered by the line segment, insert it.
do this recursively.

O(logn) since at most two node will be visited at each level.

(b) Let's x_v be the x-coordinate value of the vertical line.

starting from the root,
visit node whose range covers x_v, and
report all horizontal line segments in it;
do this until a leaf node is reached at.

O(logn + s)
where s is the number of horizontal line segments reported.

5. Bloom filter

o Bloom filter is a device that resides in internal memory and
tries to answer whether a given data is in the differential file.

That is, it accepts query of the following type:
"Is key k in the differential index/file?" and answers one of "maybe"
and "no" which have the following meaning:
- no : the key k is NOT in the differential index.
- maybe : the key k may or may not be in the differential index.

Typically, it consists of bit array of internal memory and serveral uniform and independent hash functions,

o Use with differential index and file.

[step1] Query the Bloom filter.
If the answer is "maybe", then search differential index for record address.
If the answer is "no" or if the differential index search is unsuccessful, then search the master index.
[step2] Access record from either the master file or the differential file, depending on the address obtained in [step1].
[step3] If this is an update, then update Bloom filter, differential file, transaction log.

o Advantages

By using a well designed bloom filter,
- we can avoid the search time on differential file if the data is not present there.

- the probabilty for filter error (answer from bloom filter is maybe and the data is not in the differential index) can be minimized.

6. (5)

Question asks how many black pixels are there in the image. So we just need to traverse the quadtree Q, at the same time keep a level number. If we reach a white node, we stop and report zero. If a black node, we report the number of pixels indicated by the level number (here we assume the partitions are uniform, so the number of pixels at each level can be computed quickly). If we happen upon a grey node, we recursively traverse its children, sum up the numbers reported, and report the sum.