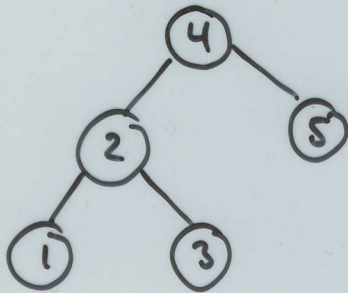
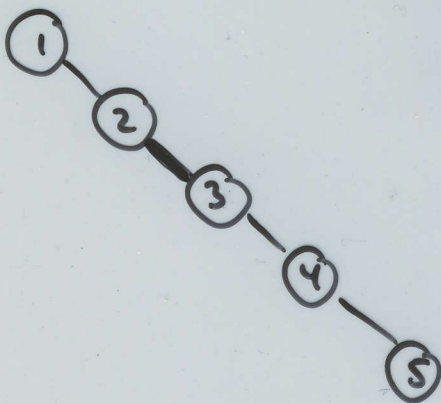


4, 2, 1, 3, 5

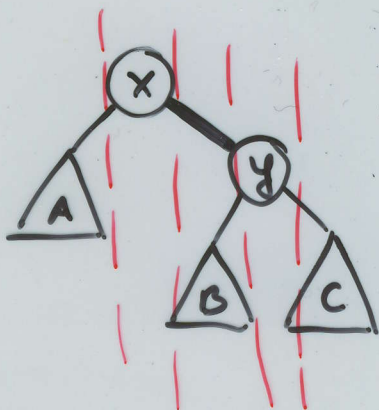
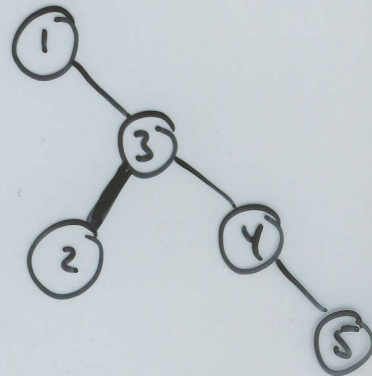


1, 2, 3, 4, 5



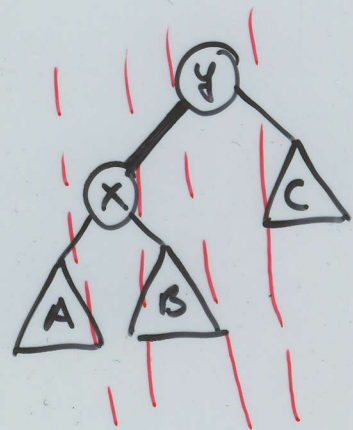
venstre -
rotation →

højre -
← rotation



venstre
→

←
højre



Indbyg rotationer i update-op., så

- træet altid er balanceret
- update-op. stadig er $O(h)$

Rød-sort træ:

Binært søgetræ, hvor:

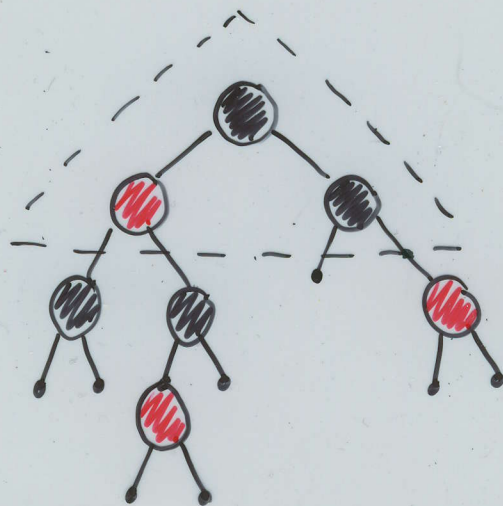
1. Hver knude er sort eller rød
2. Røden er sort
3. Bladene er sorte

4. Røde knuder har sorte børn

5. For enhver knude v gælder alle stier fra v til et blad har samme # sorte knuder

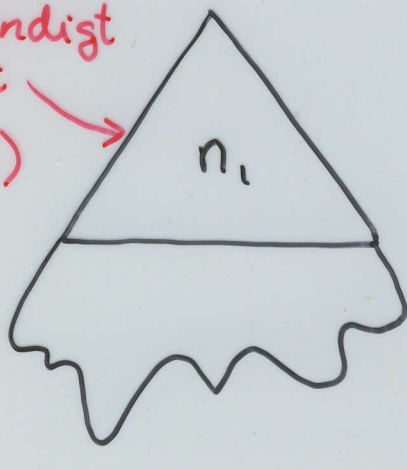
Sikrer
balance

Eks:



sort højde = 2

fuldstændigt
binært
træ (s.)



s.h.

\leq s.h. (4.)

$$n \geq n_1 = \sum_{i=0}^{s.h.-1} 2^i = 2^{s.h.} - 1$$

\Leftrightarrow

$$2^{s.h.} \leq n+1$$

\Leftrightarrow

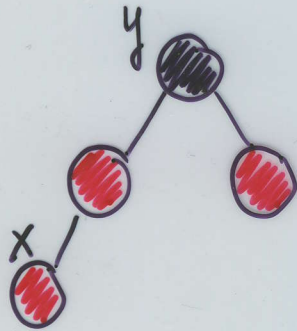
$$s.h. \leq \log_2(n+1)$$

\Leftrightarrow

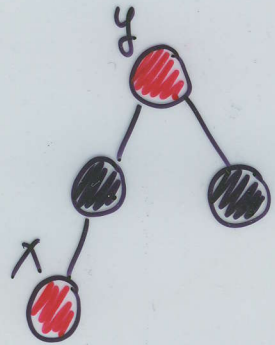
$$h \leq 2 \cdot \log_2(n+1)$$

(Indsæt X)

Tilfælde 1: x's onkel er rød

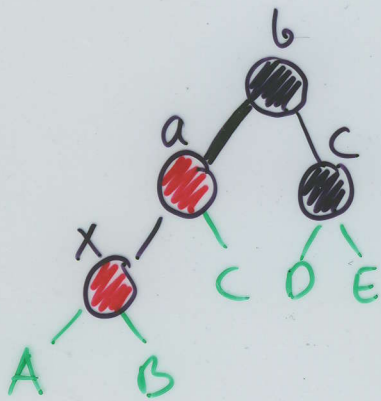


omfarvning
→

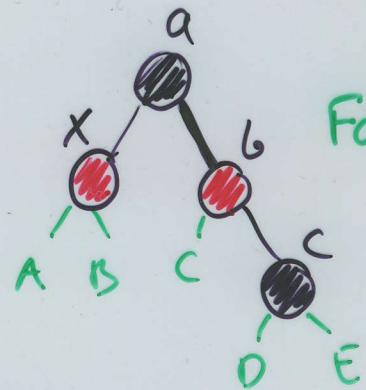


Hvis y er røder:
Faru y sort

Tilfælde 3: x's onkel er sort, og x er et venstre-barn

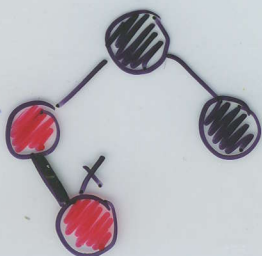


højre-rot. +
omfarvning
→

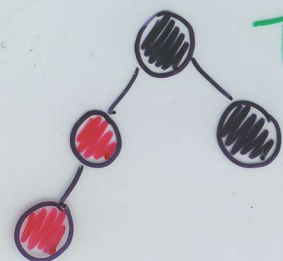


Færdig

Tilfælde 2: x's onkel er sort, og x er et højre-barn

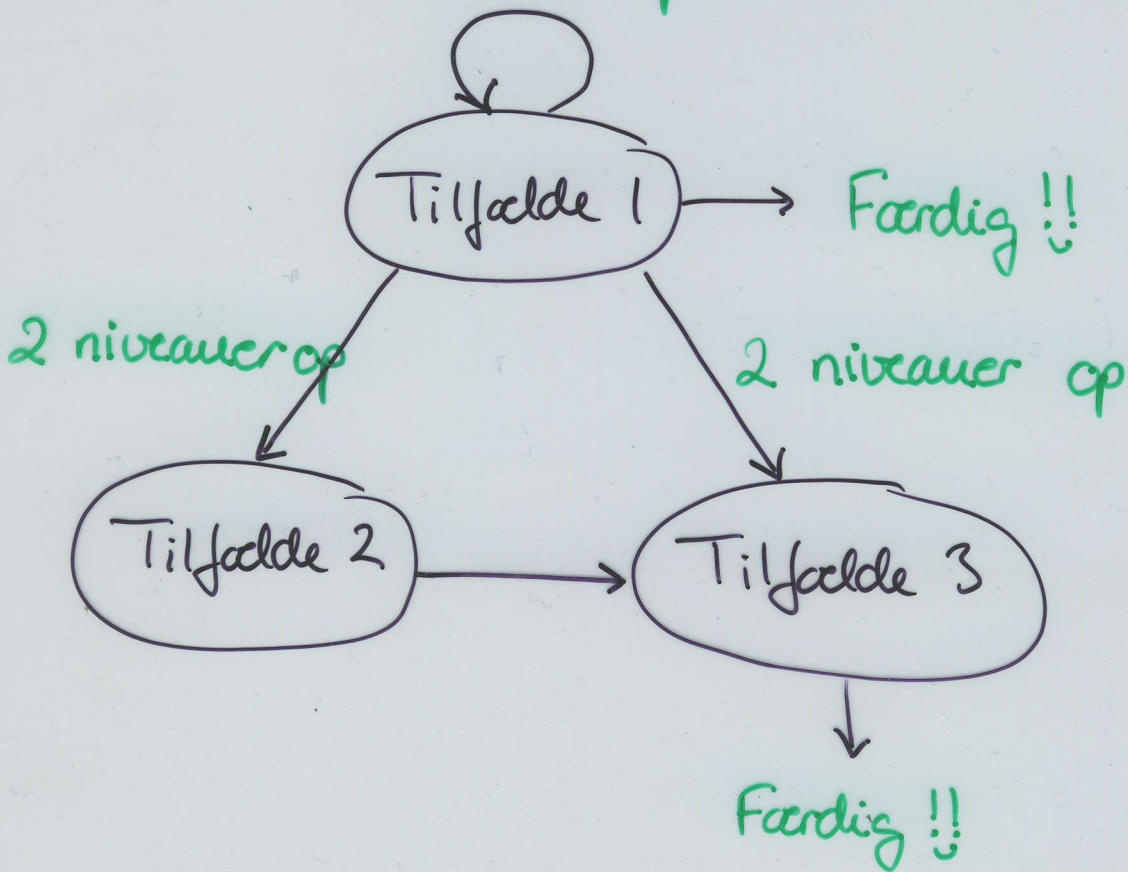


venstre-rot.
→



Tilfælde

2 niveauer op



(Slet 2)

z: logisk slettet knude

y: strukturelt slettet knude

x: y's barn (ev. et blad)

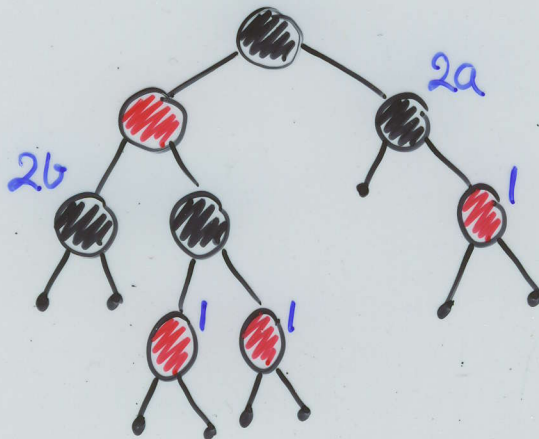
1. y rød: OK

2. y sort:

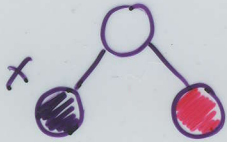
2a. x rød: OK - x farves sort

2b. x sort: Stier gennem x har en sort knude for lidt

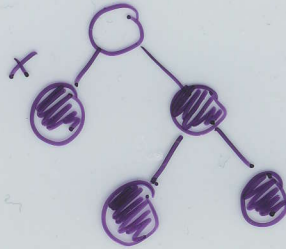
OK, hvis x var "dobbelt sort"



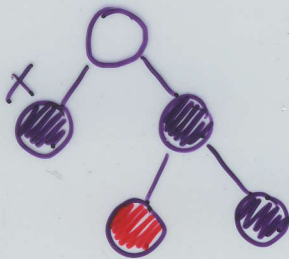
Tilfælde 1



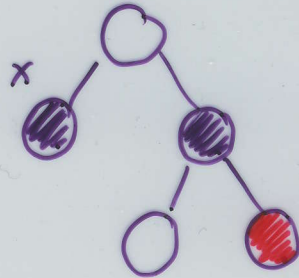
Tilfælde 2



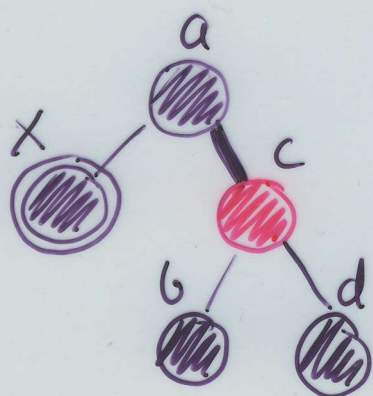
Tilfælde 3



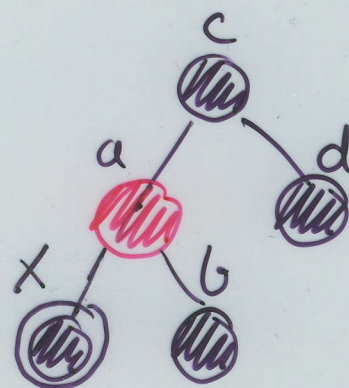
Tilfælde 4



Tilfælde 1: X's bror er rød

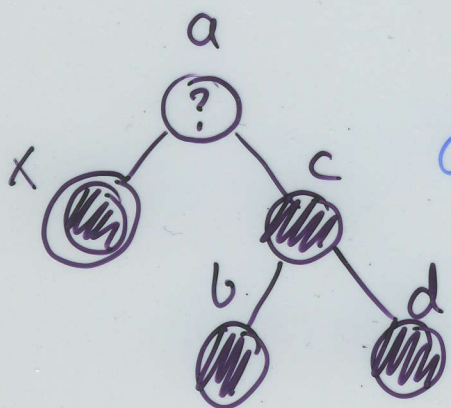


venstre-rot. +
omfarøning

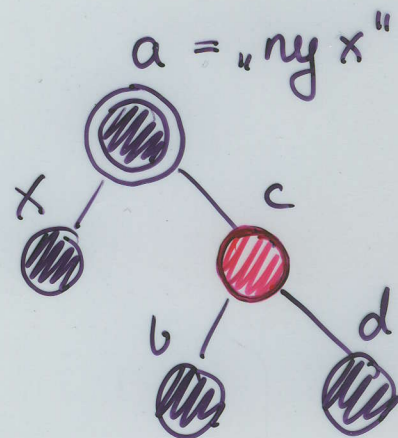


Tilfælde 2, 3
eller 4

Tilfælde 2: X's bror er sort, og
X's nevøer er sorte



omfarøning

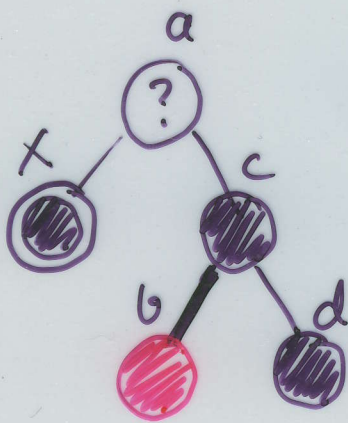


? = rød : færdig!

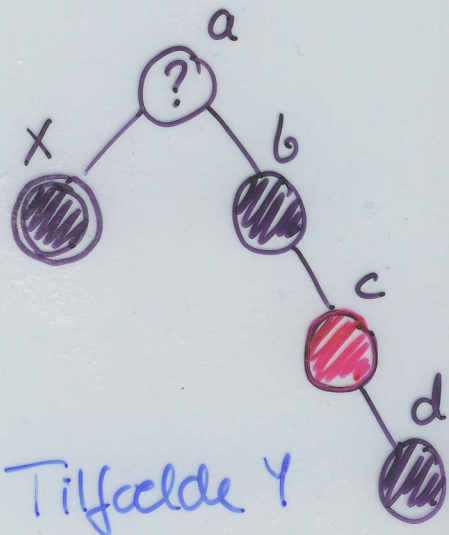
? = sort : ~~Tilfælde~~

problemet er
flyttet opad.

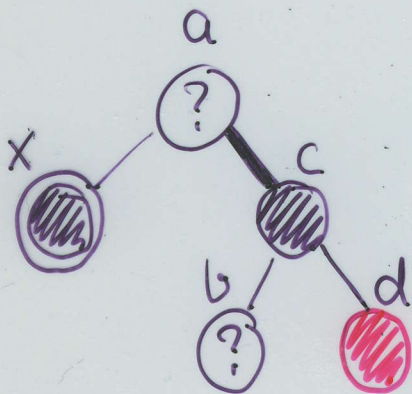
Tilfælde 3: x's bror er sort,
 x's "venstre nevø" er rød,
 x's "højre nevø" er sort



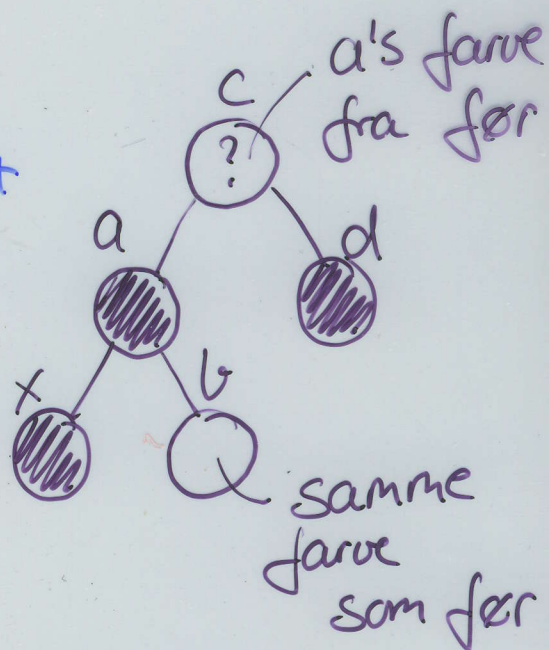
højre-rot. +
 →
 omfarvning



Tilfælde 4: x's bror er sort, og
 x's "højre nevø" er rød



venstre-rot. +
 →
 omfarvning



færdig!

