CENG 213 Veri Yapıları 5: AVL Ağaçları

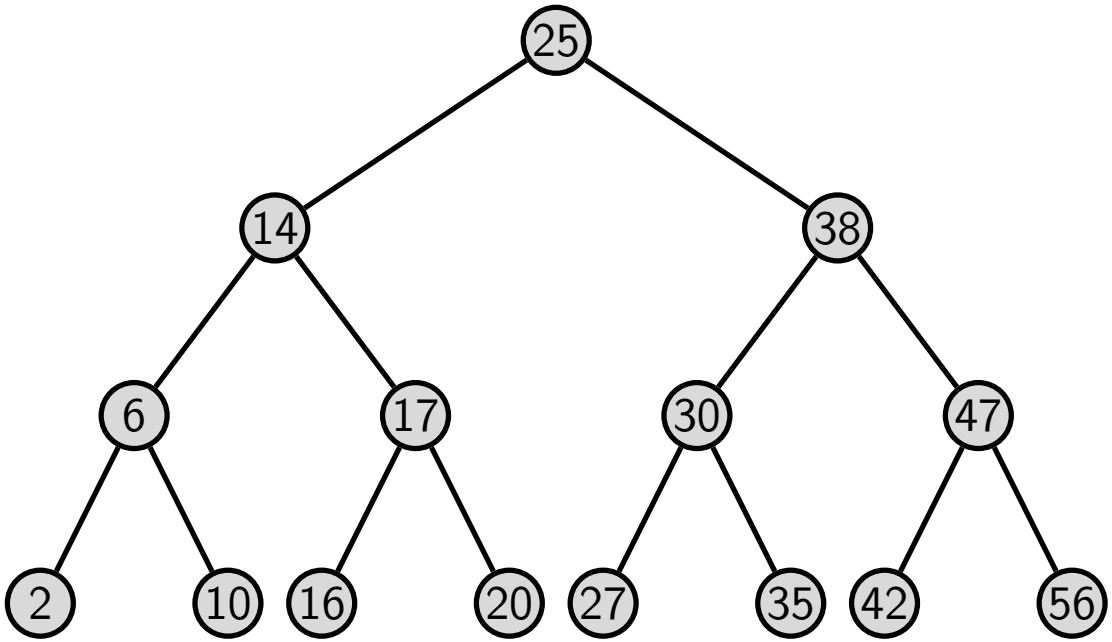
Öğr.Gör. Şevket Umut ÇAKIR

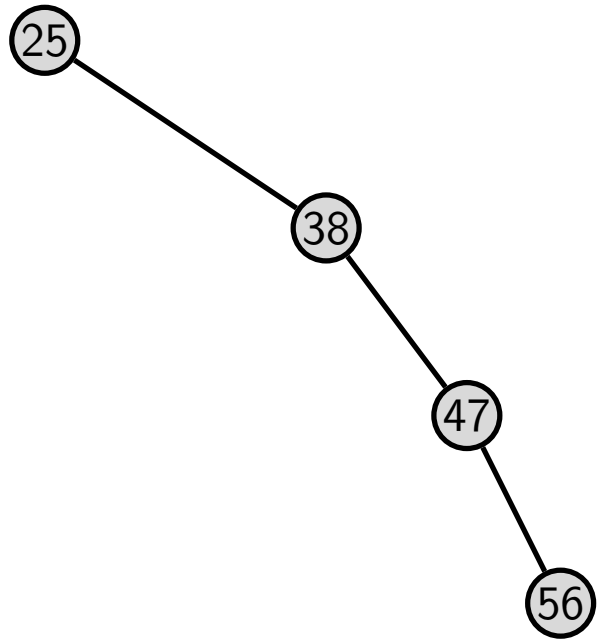
Pamukkale Üniversitesi

Hafta 5

Anahat

Dengeli Ağaçlar





- Yukardaki n elemanlı ikili arama ağaçlarda arama ve ekleme işlemleri en iyi ve en kötü durumda kaç adımda yapılır?

AVL Ağaçları

- İsmini geliştiricileri olan Adelson-Velskii ve Landis'den almıştır
- Dengeli bir ikili arama ağacıdır
- Dengeleme işlemi ekleme ve silme sırasında yapılır
- Her düğüm için denge faktörü -1'den küçük veya 1'den büyük olamaz
- Denge faktörü bir düğümün hangi yöne yatık olduğunu gösterir

Denge Faktörü

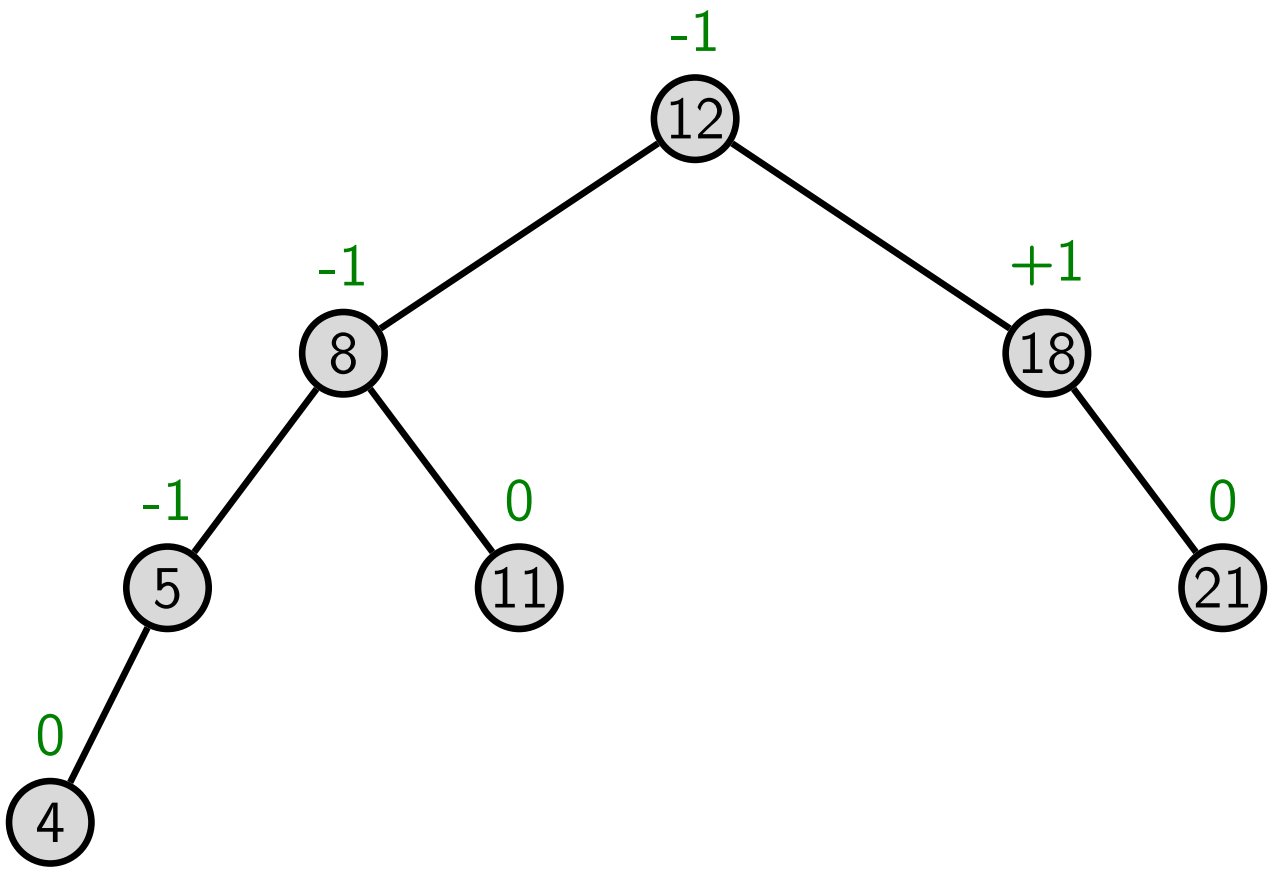
Yükseklik

Bir düğümün yüksekliği düğüm ile soyundan gelen yapraklardan en uzağı arasındaki mesafedir.

Denge Faktörü

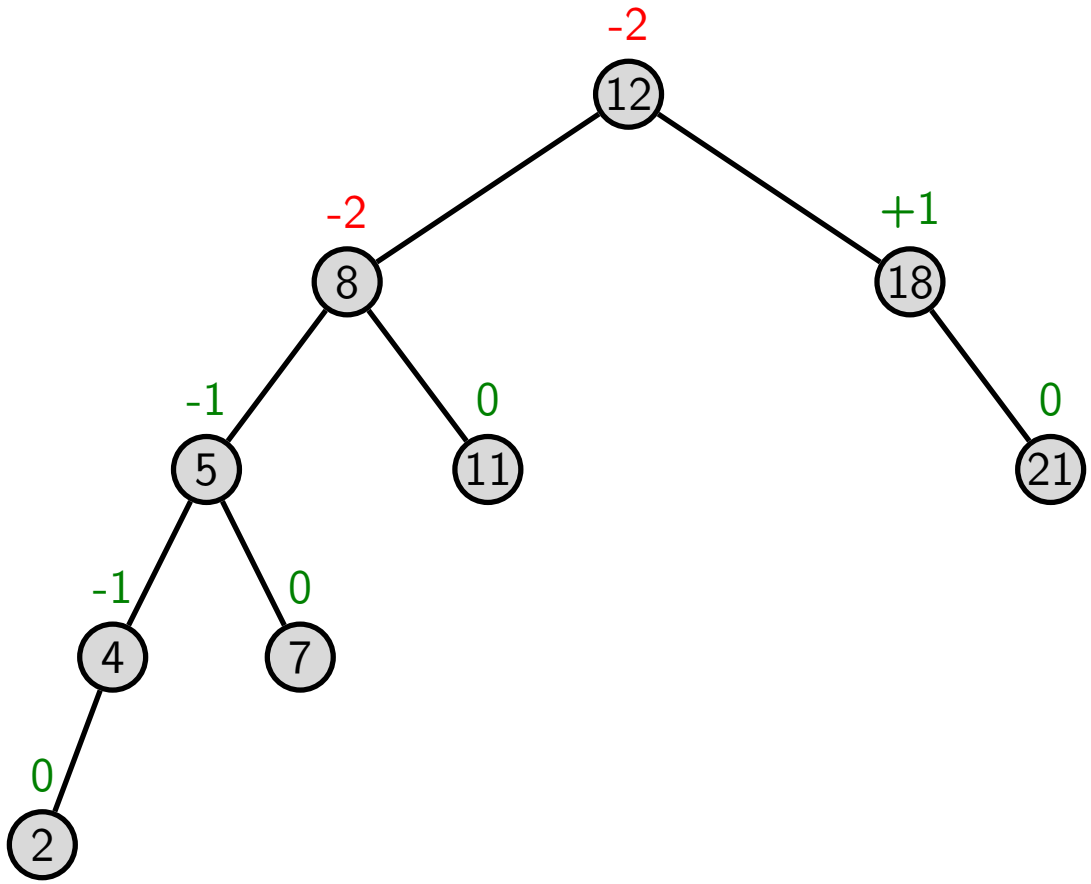
Sağ çocuğun yüksekliği ile sol çocuğun yüksekliği arasındaki farktır.

Denge Faktörü/Balance Factor



Şekil: AVL Ağacı(Dengeli İkili Arama Ağacı)

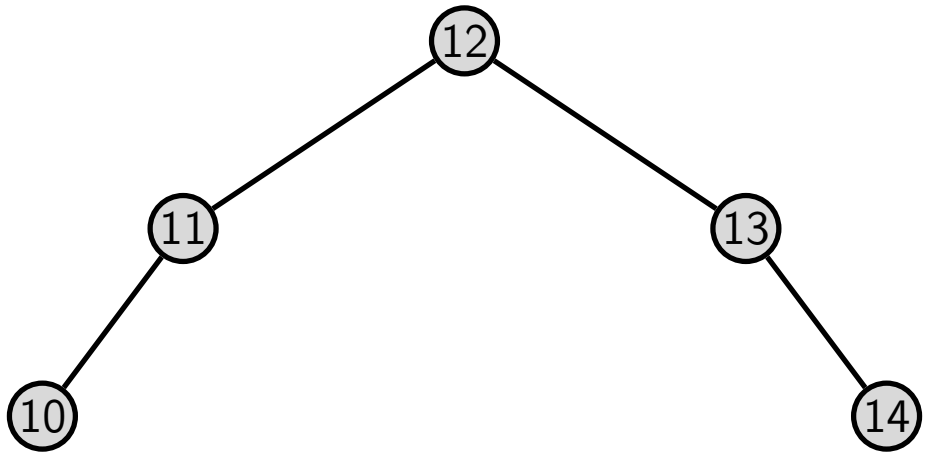
Denge Faktörü/Balance Factor



Şekil: AVL Ağacı(Dengeli İkili Arama Ağacı)

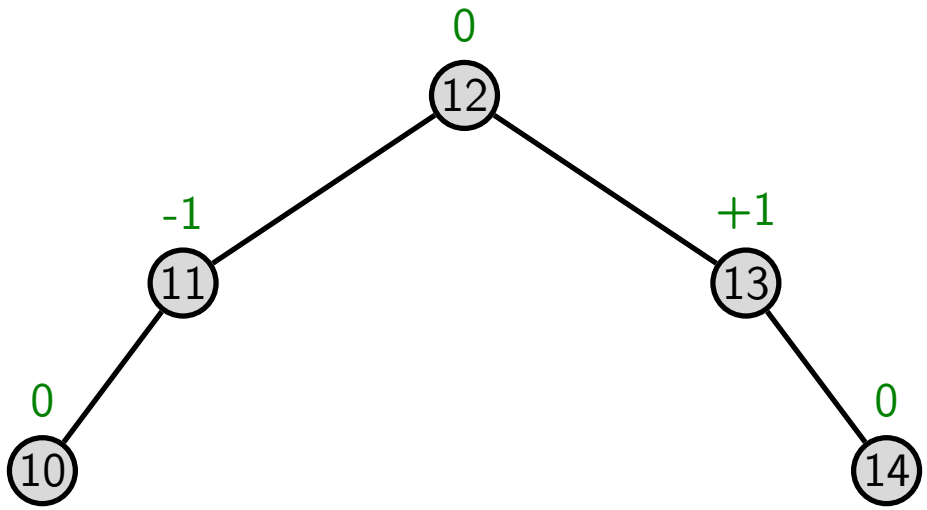
AVL Ağaçları

Aşağıdaki ağaç bir AVL ağacı mıdır?



AVL Ağaçları

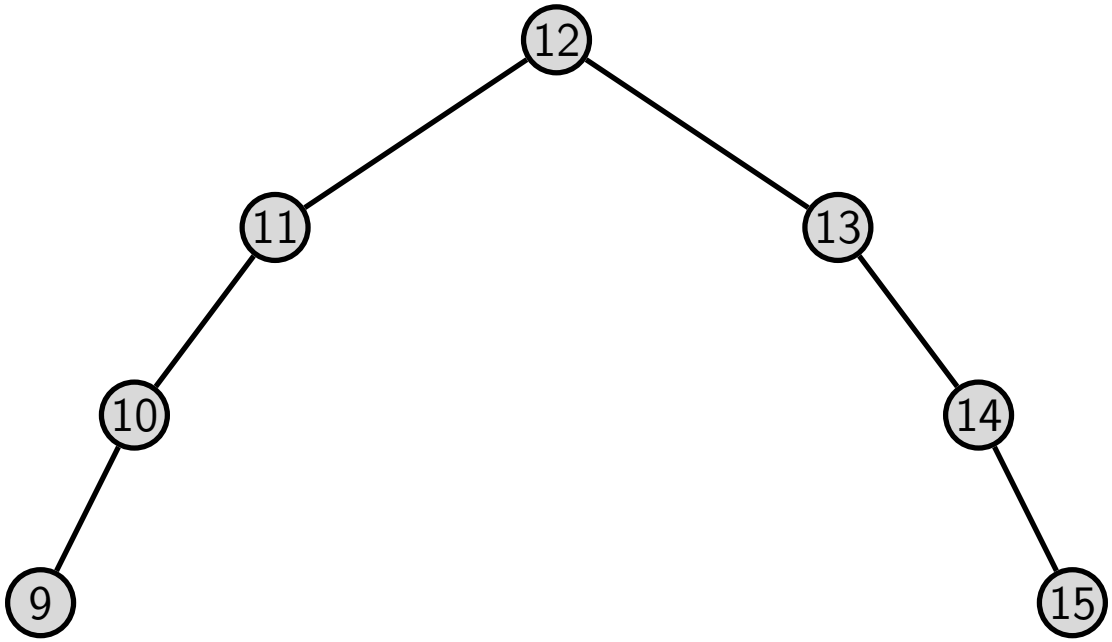
Aşağıdaki ağaç bir AVL ağacı mıdır?



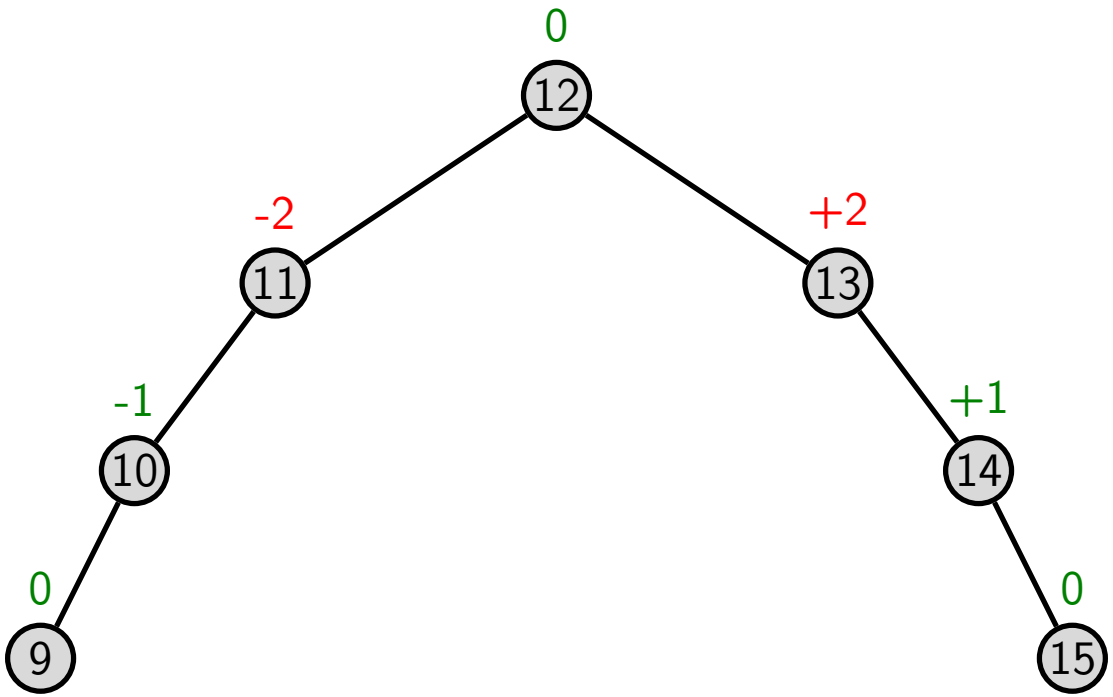
Şekil: AVL Ağacıdır

AVL Ağaçları

Aşağıdaki ağaç bir AVL ağacı mıdır?



Aşağıdaki ağaç bir AVL ağacı mıdır?



Şekil: AVL Ağacı değildir

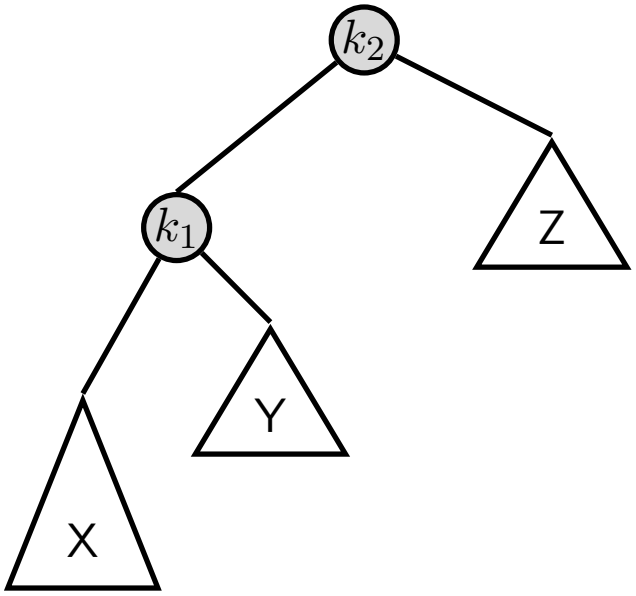
Ekleme

- Ekleme işlemi ikili arama ağaçlarındaki gibidir
- Ekleme işlemi sırasında denge bozulabilir
- Dengesi bozulan düğümler eklenen düğümden köke kadarki yolda olacaktır
- Dengenin tekrar sağlanması için döndürme işlemleri yapılır
- 4 farklı durum ortaya çıkabilir
- Tekli veya ikili döndürme ile ağaç tekrar dengelenir

Ekleme

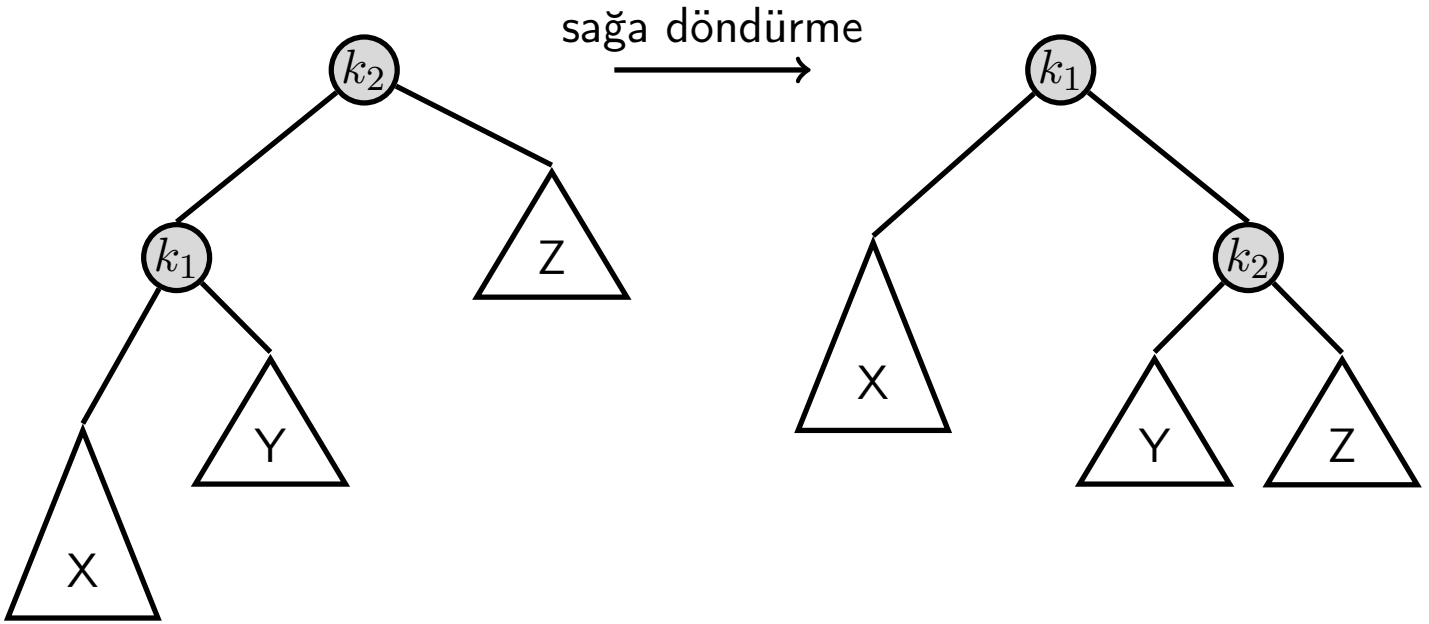
- Yeni eklenen düğümden köke doğru gittikçe dengesi bozulan ilk düğüm α olsun
- 4 farklı ekleme biçiminden ötürü denge bozulmuş olabilir:
  1. α'nın sol çocuğunun soluna ekleme
  2. α'nın sol çocuğunun sağına ekleme
  3. α'nın sağ çocuğunun soluna ekleme
  4. α'nın sağ çocuğunun sağına ekleme
- Durum 1 ve 4 tekli döndürme ile düzeltilebilir
- Durum 2 ve 3 için çift döndürme gereklidir

Tekli Döndürme(Sağa)



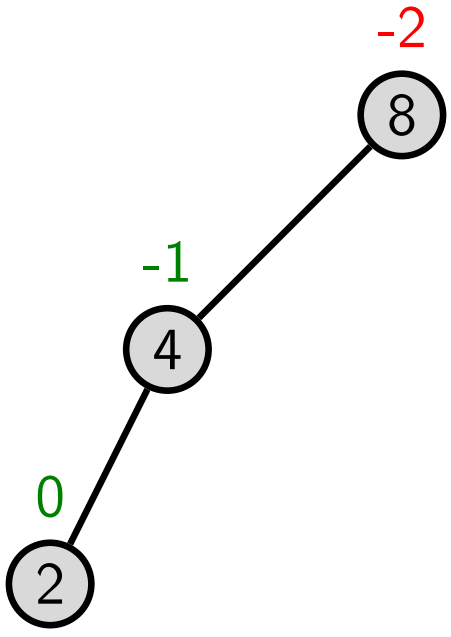
Şekil: Durum 1'in çözümü

Tekli Döndürme(Sağa)

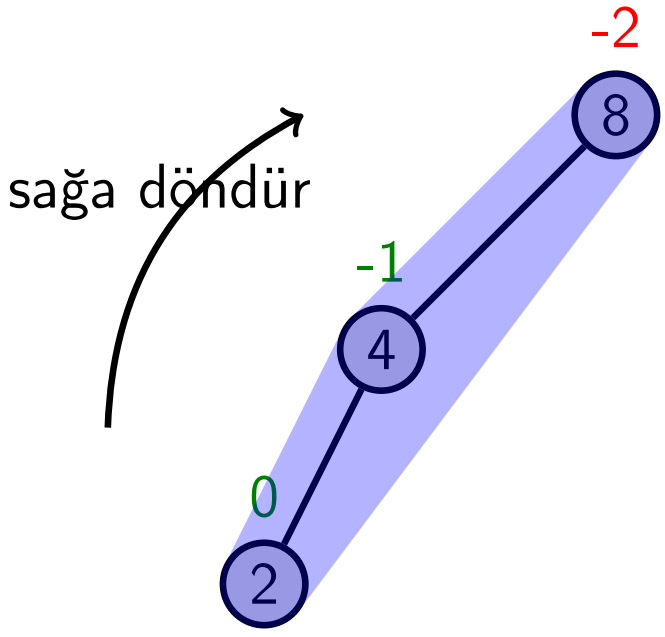


Şekil: Durum 1'in çözümü

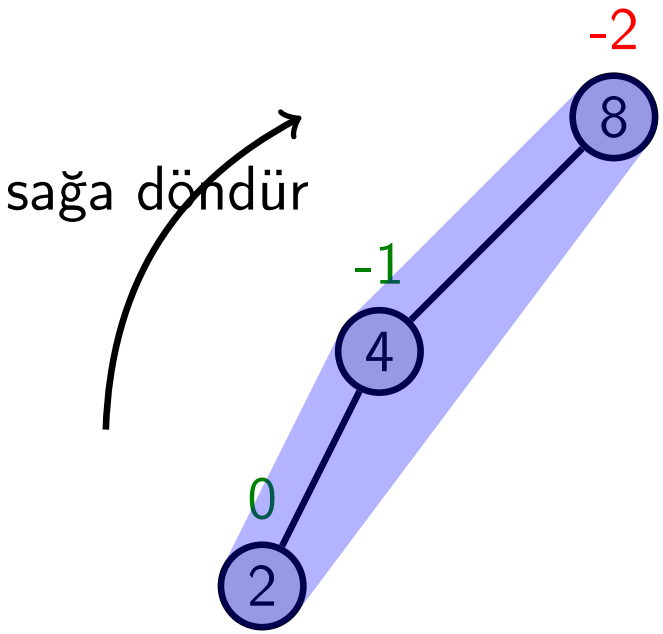
Durum 1 Örnek

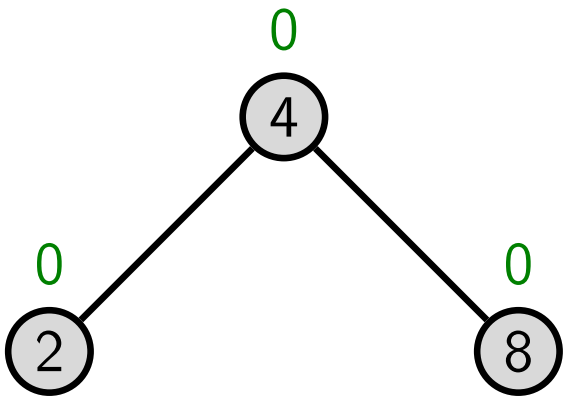


Durum 1 Örnek

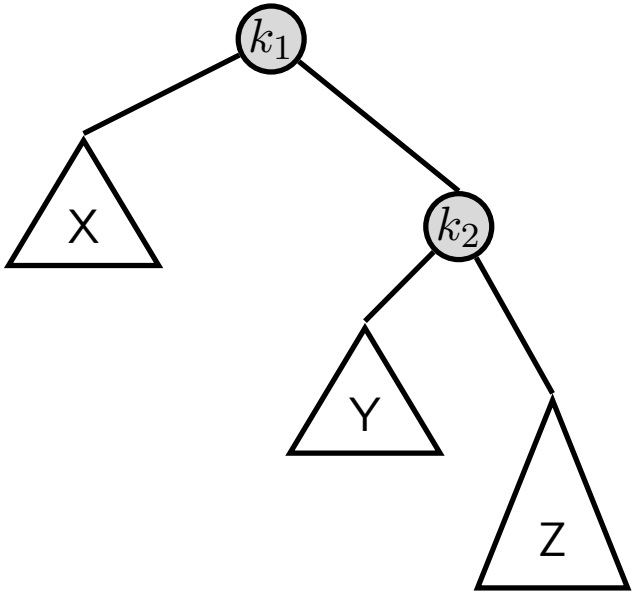


Durum 1 Örnek



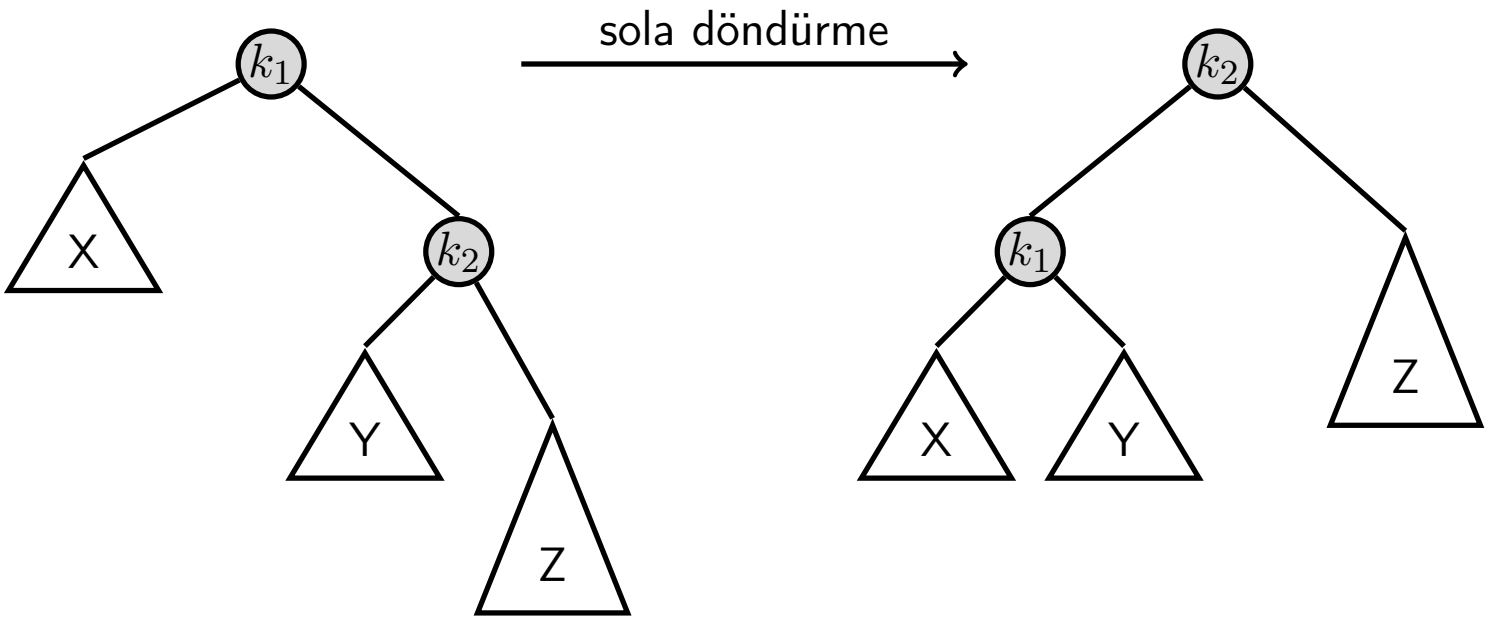


Tekli Döndürme(Sola)



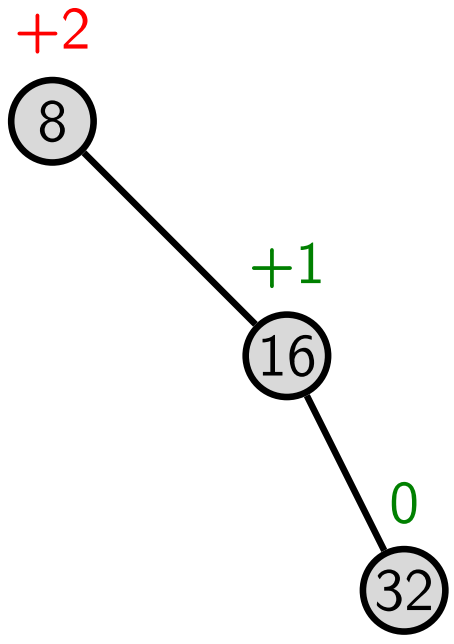
Şekil: Durum 4'ün çözümü

Tekli Döndürme(Sola)

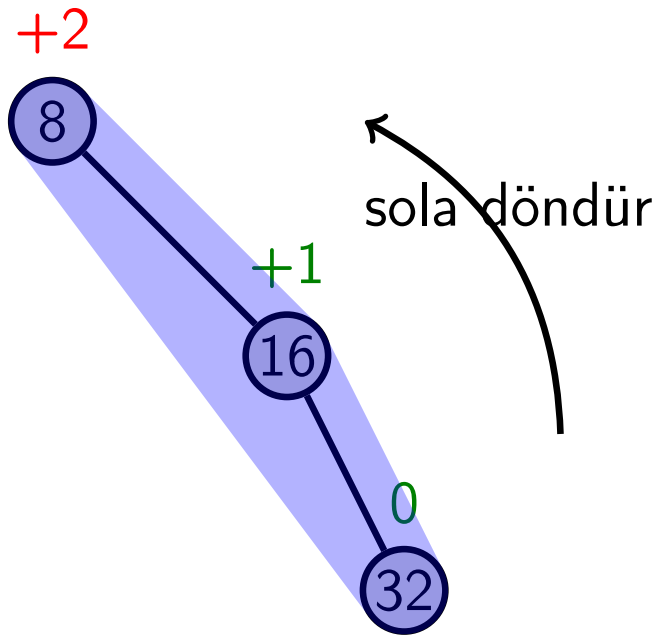


Şekil: Durum 4'ün çözümü

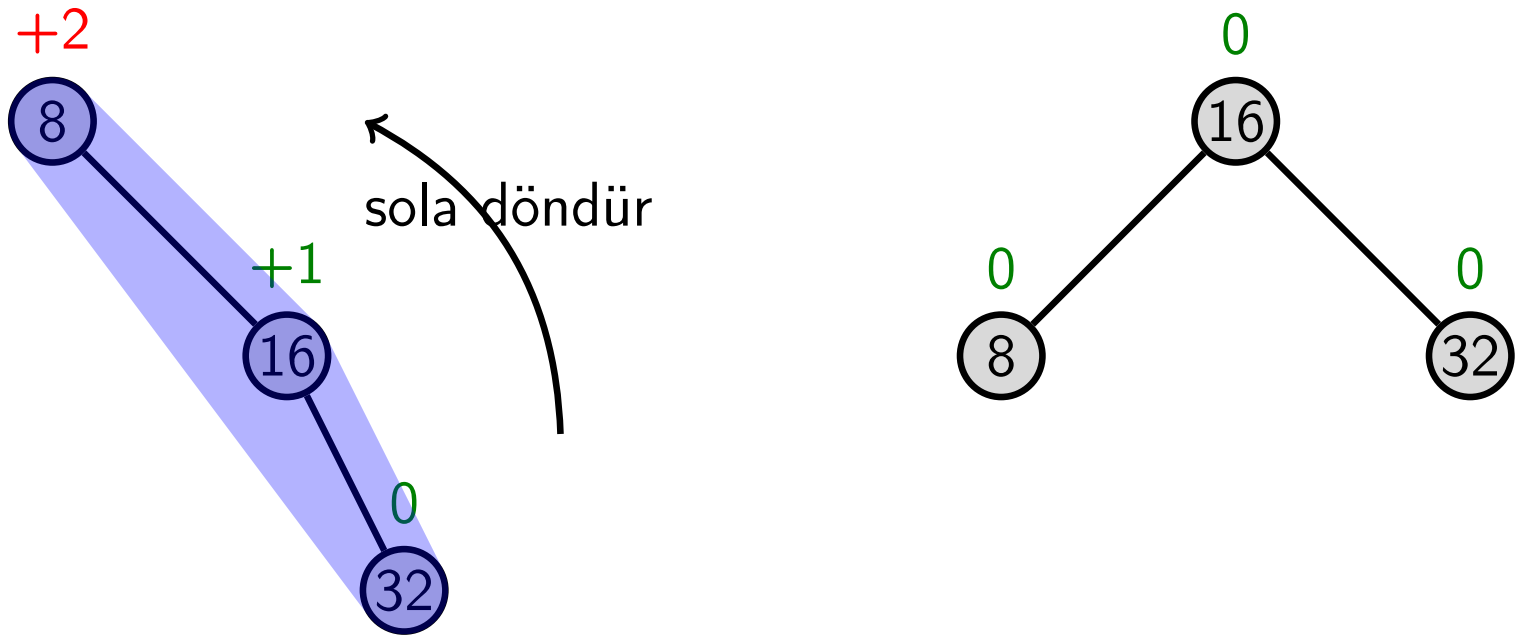
Durum 4 Örnek



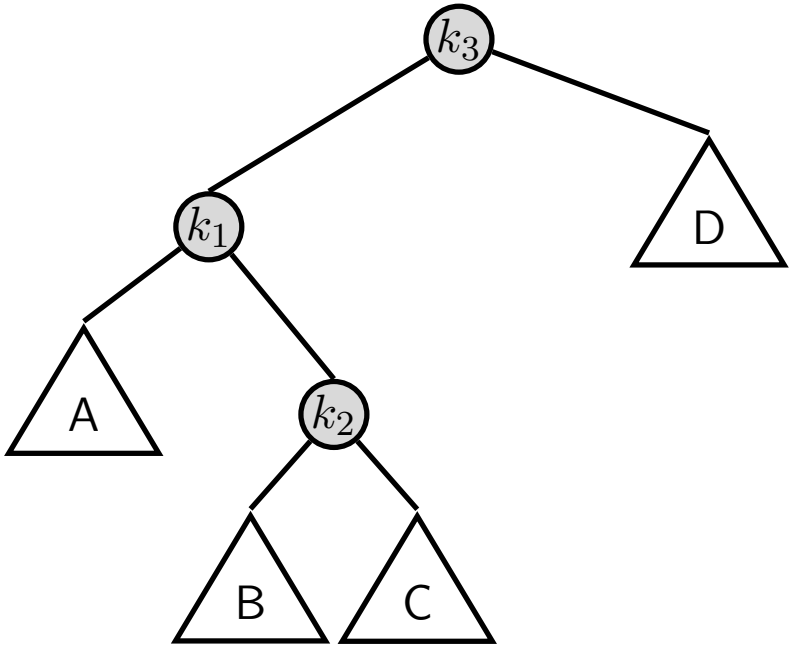
Durum 4 Örnek



Durum 4 Örnek

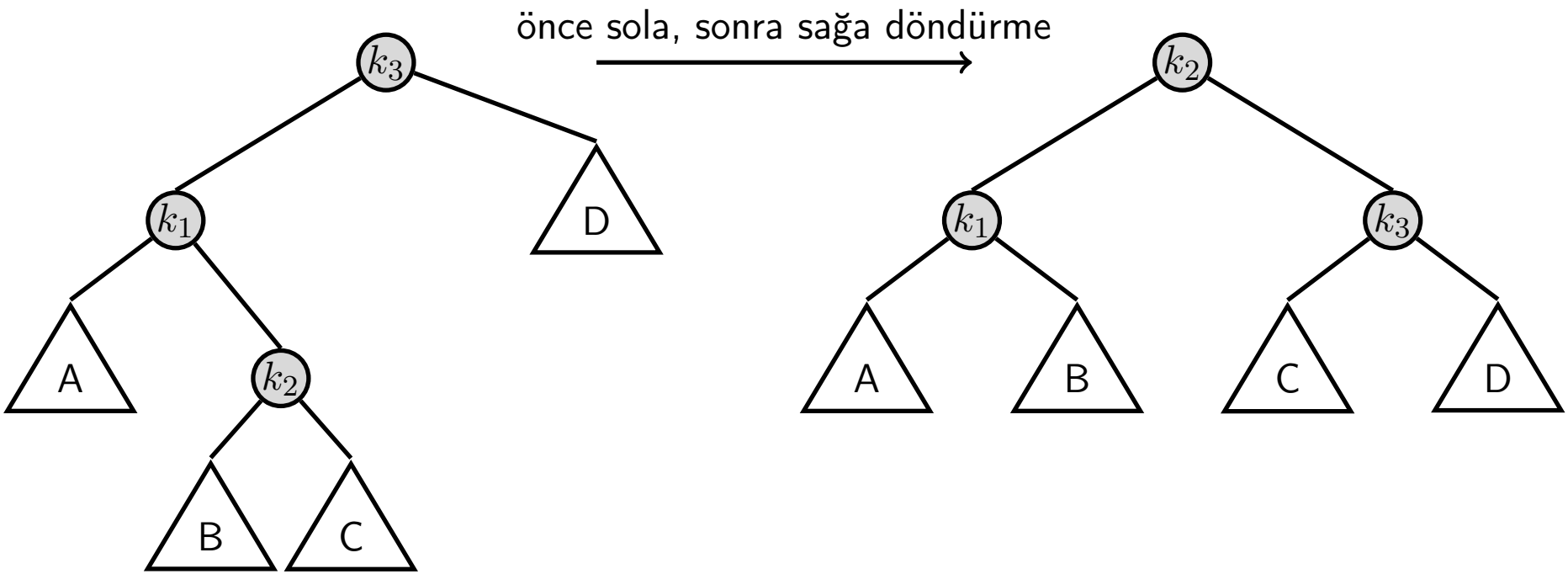


Çift Döndürme(sol, sağ)



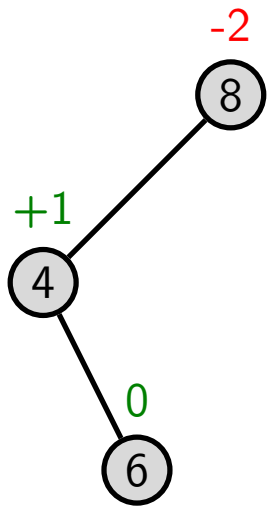
Şekil: Durum 2'nin çözümü

Çift Döndürme(sol, sağ)

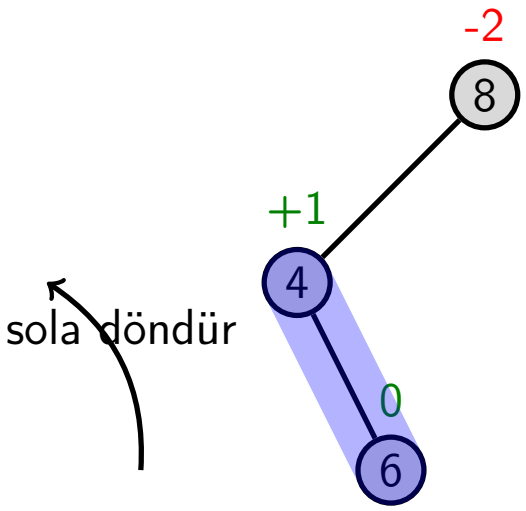


Şekil: Durum 2'nin çözümü

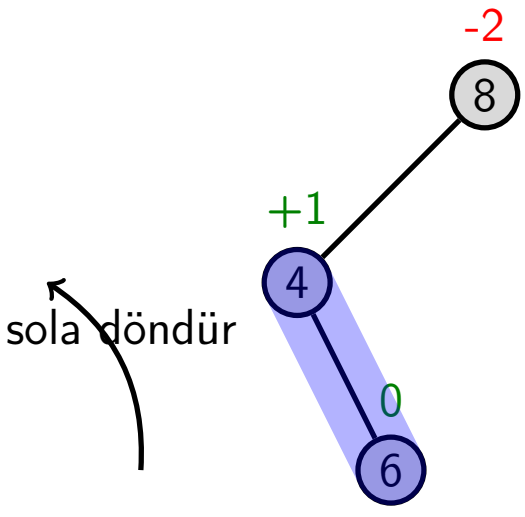
Durum 2 Örnek

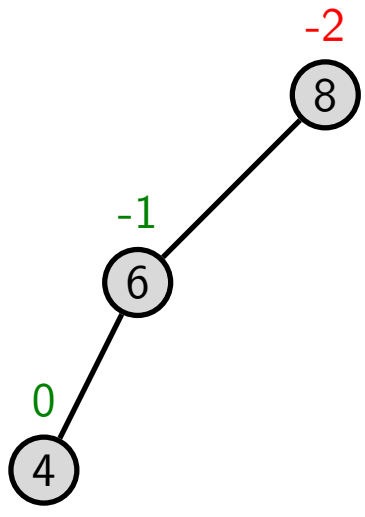


Durum 2 Örnek

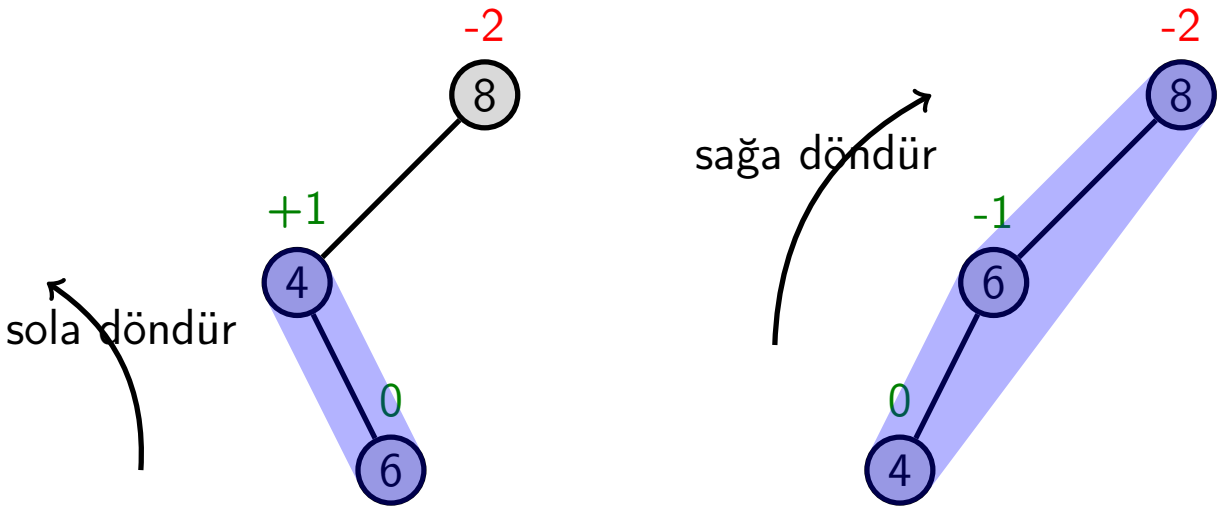


Durum 2 Örnek

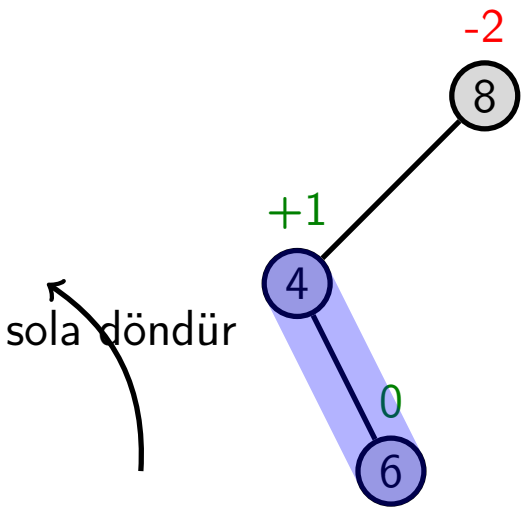


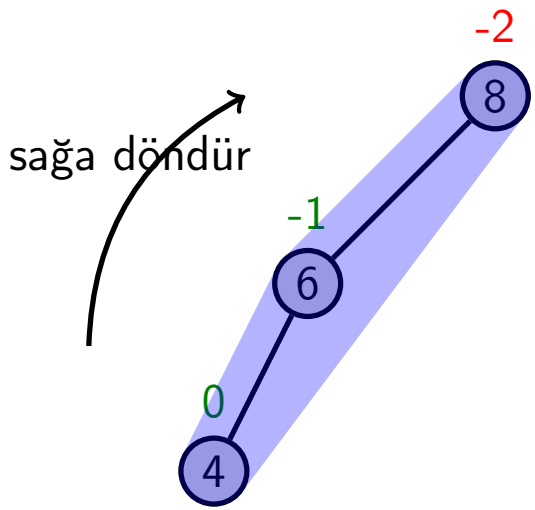


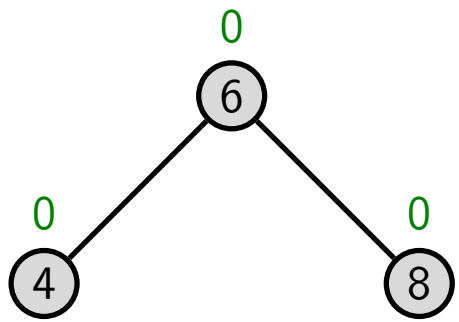
Durum 2 Örnek



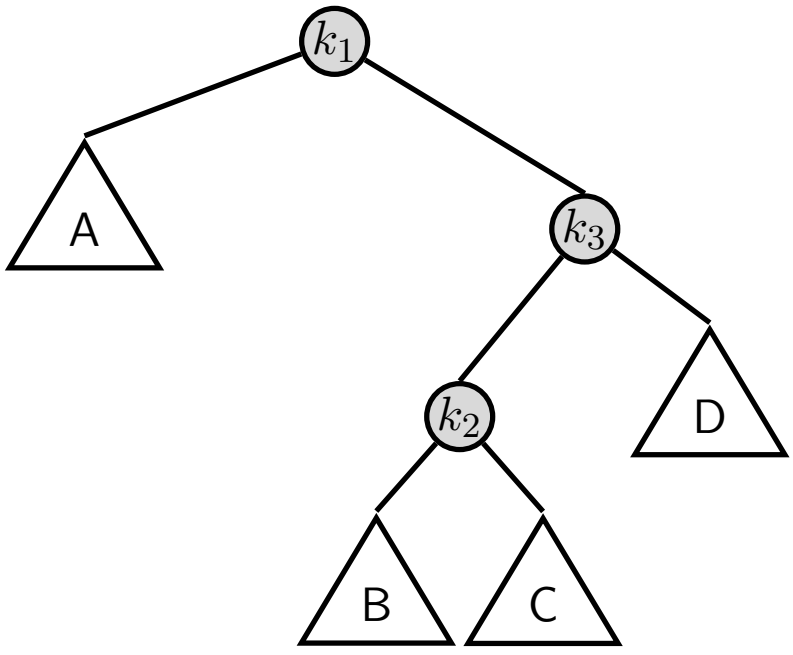
Durum 2 Örnek





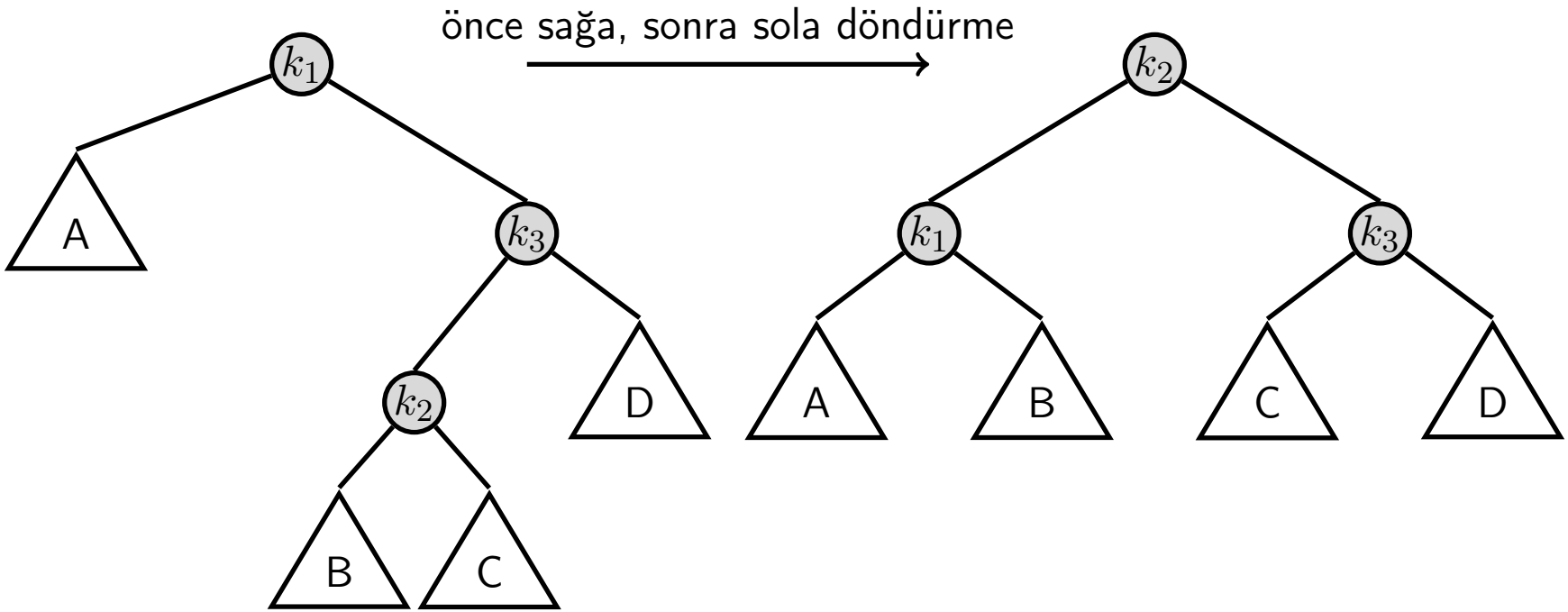


Çift Döndürme(sağ, sol)



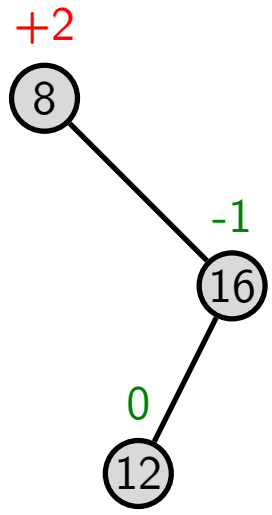
Şekil: Durum 3'ün çözümü

Çift Döndürme(sağ, sol)

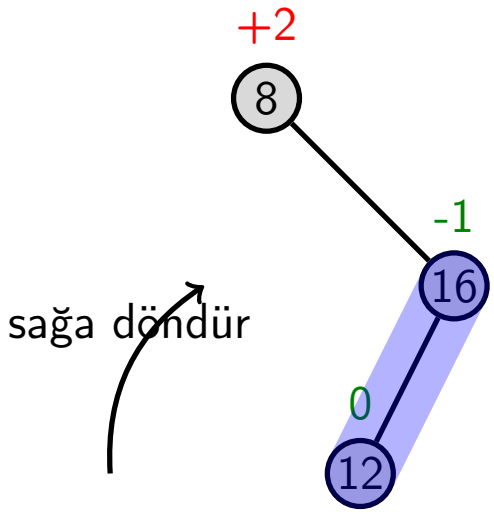


Şekil: Durum 3'ün çözümü

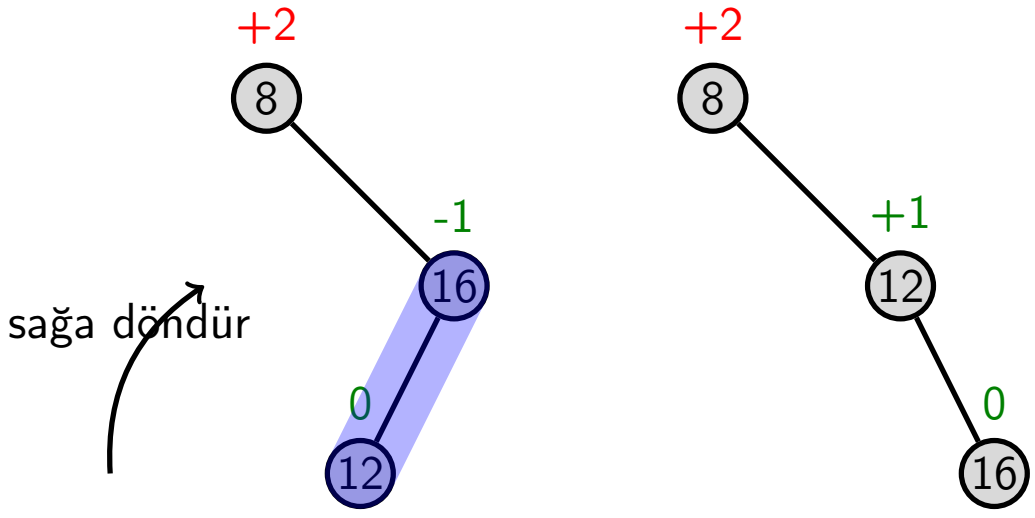
Durum 3 Örnek



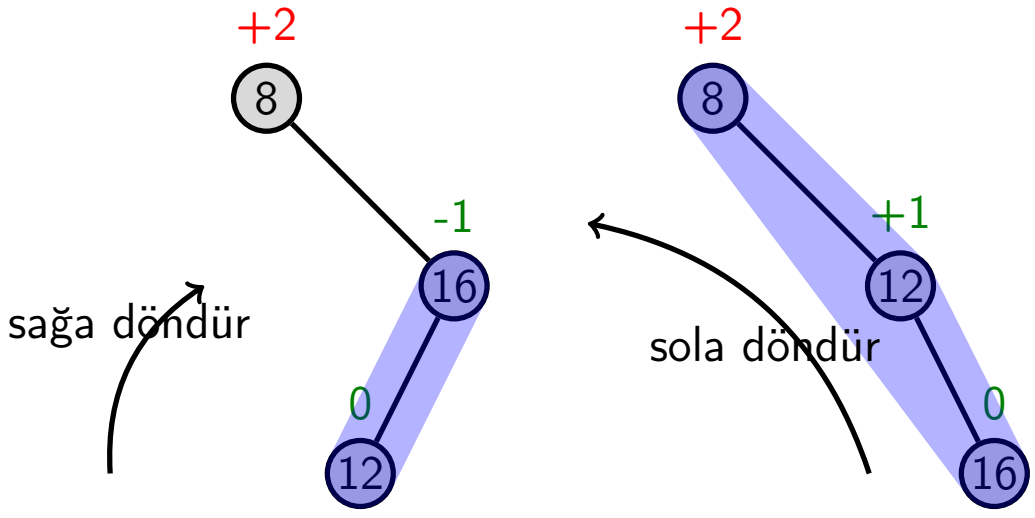
Durum 3 Örnek



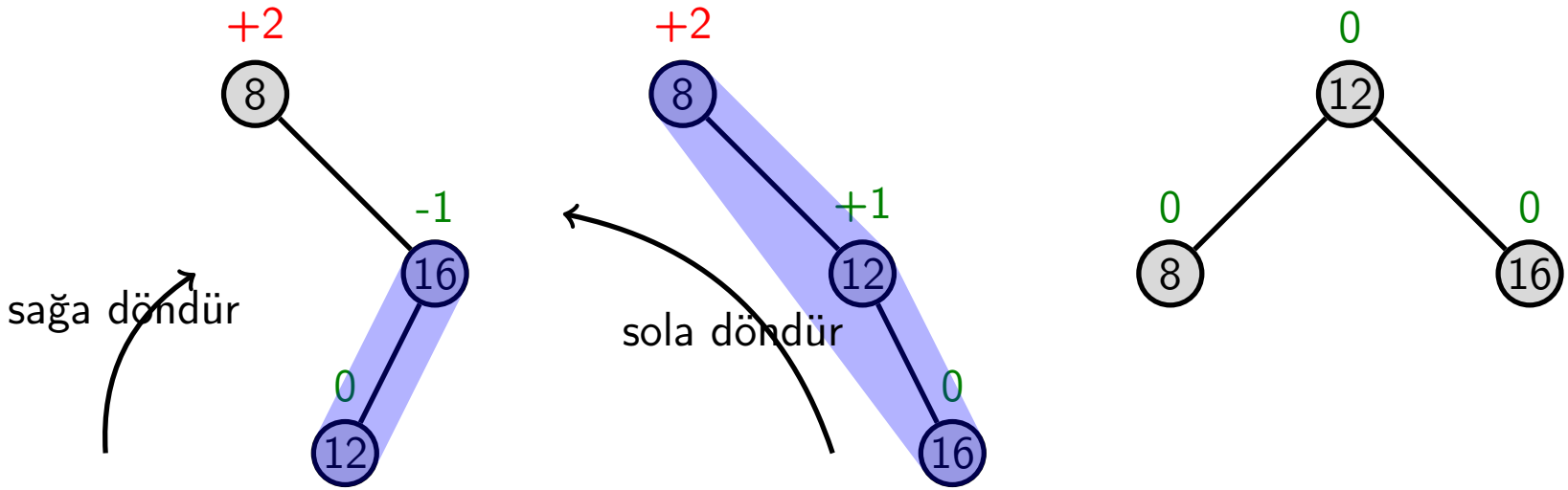
Durum 3 Örnek



Durum 3 Örnek



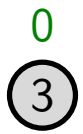
Durum 3 Örnek



Bir AVL ağacına 3, 2, 1, 4, 5, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9 değerlerini sırasıla ekleyelim.

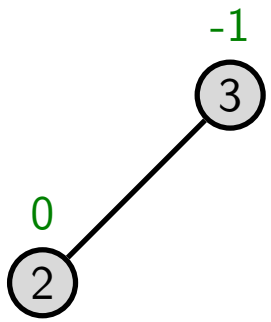
3 Ekle

Eklenecek: ~~3~~, 2, 1, 4, 5, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



2 Ekle

Eklenecek: ~~3~~, ~~2~~, 1, 4, 5, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



1 Ekle

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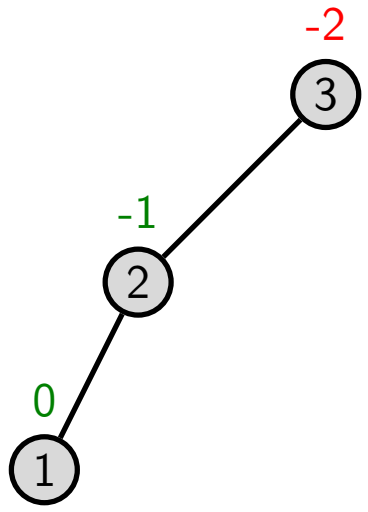

1 Ekle

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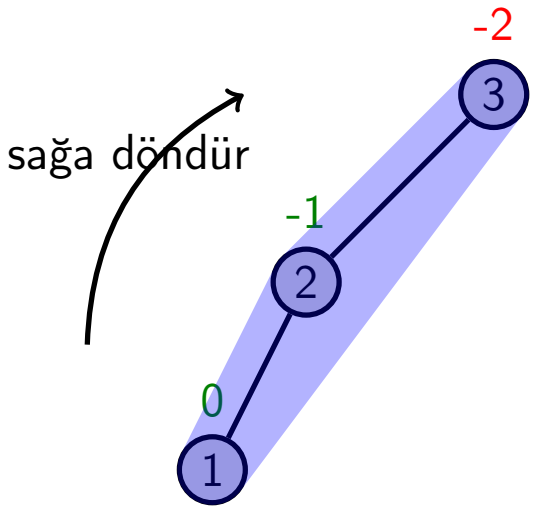
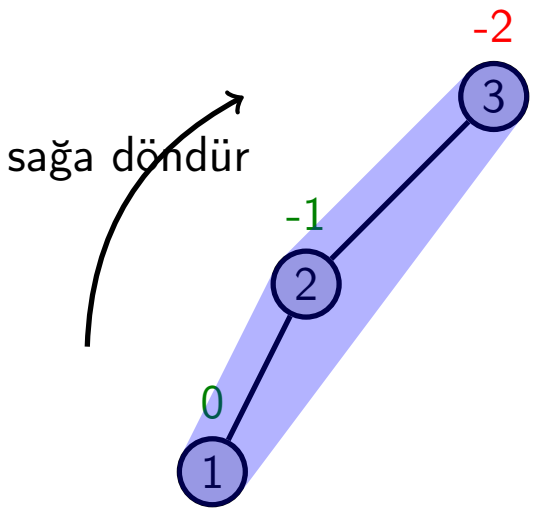
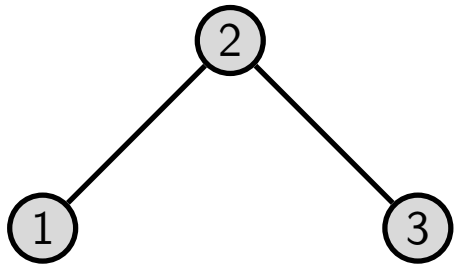


1 Ekle

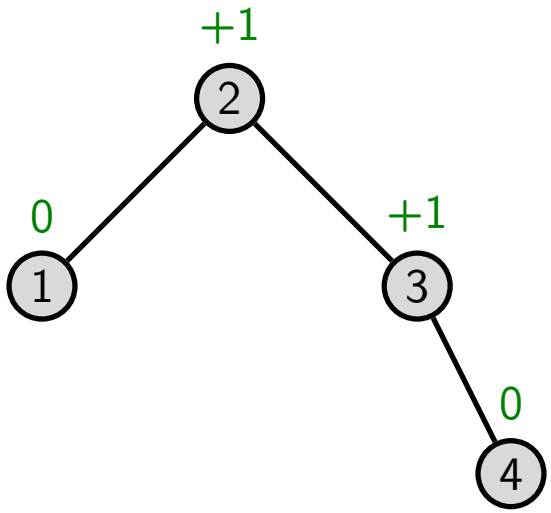
Eklenecek: ~~3~~, ~~2~~, ~~1~~, 4, 5, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9





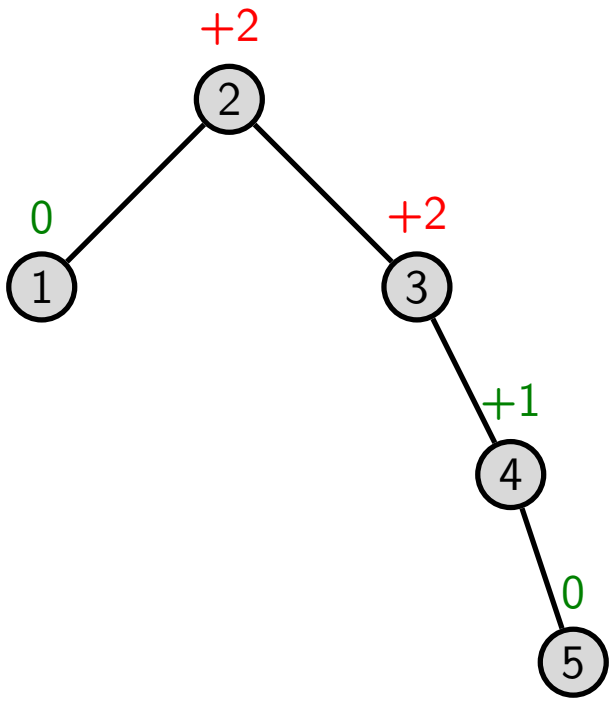
4 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, 5, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



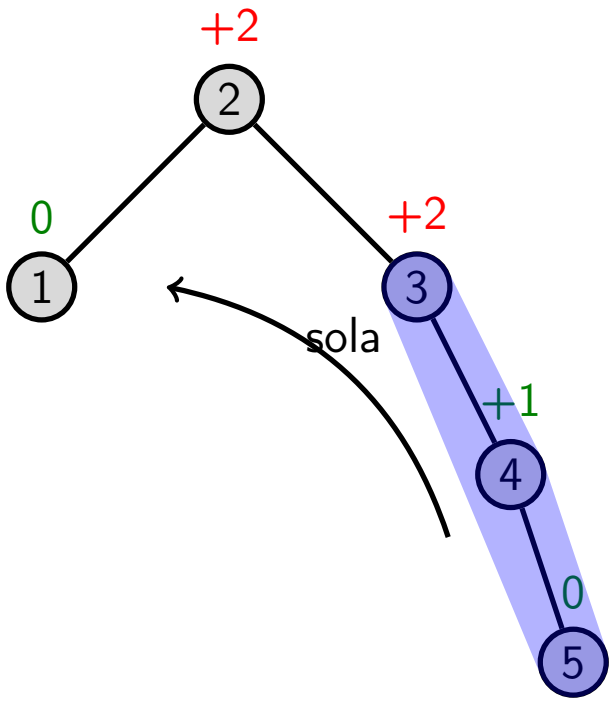
5 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



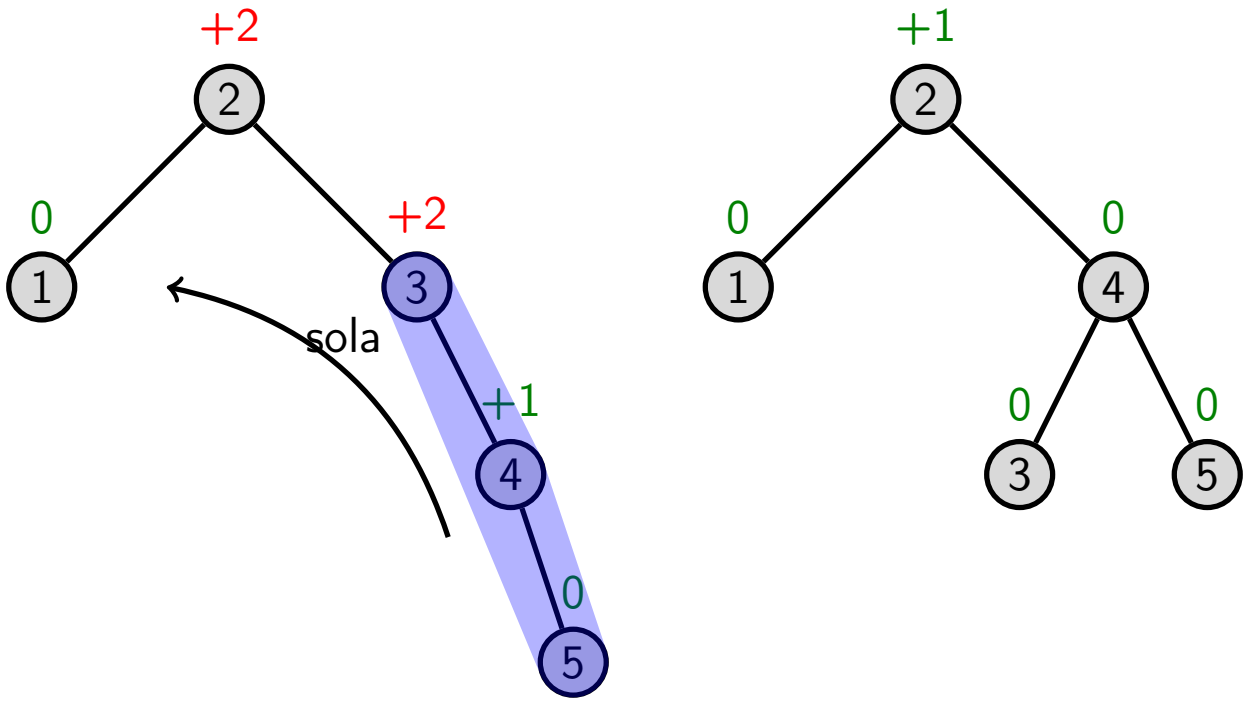
5 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



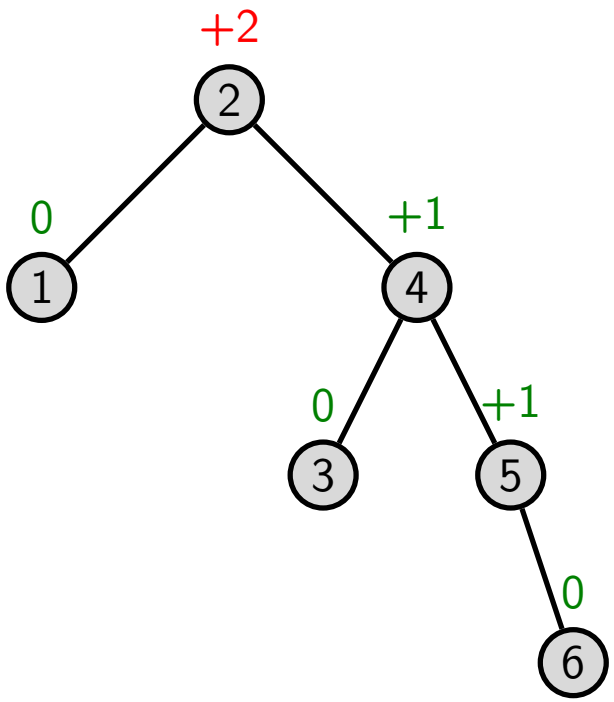
5 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, 6, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



6 Ekle

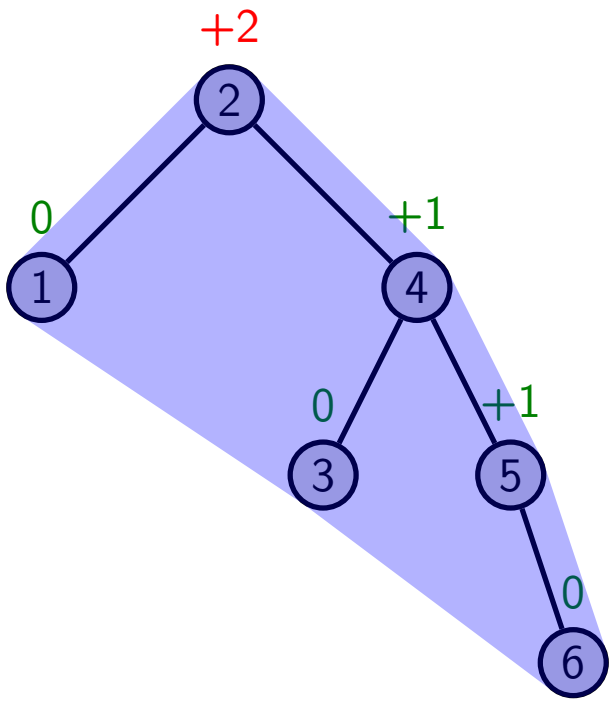
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

6 Ekle

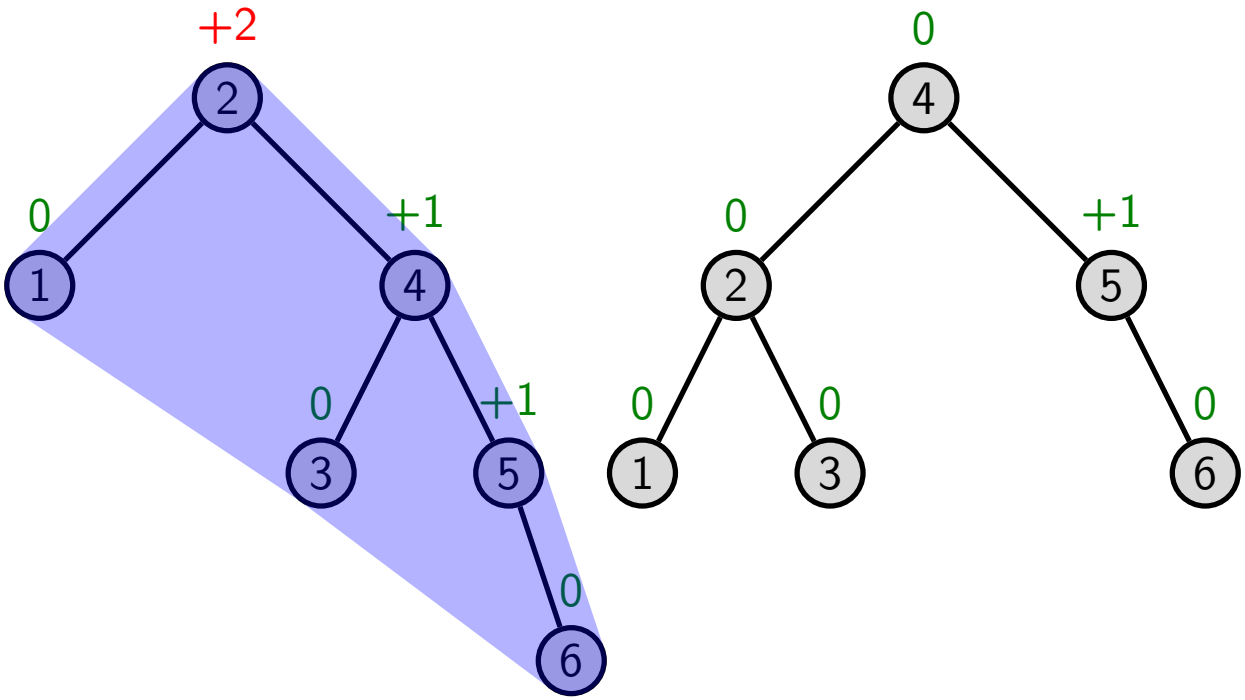
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

6 Ekle

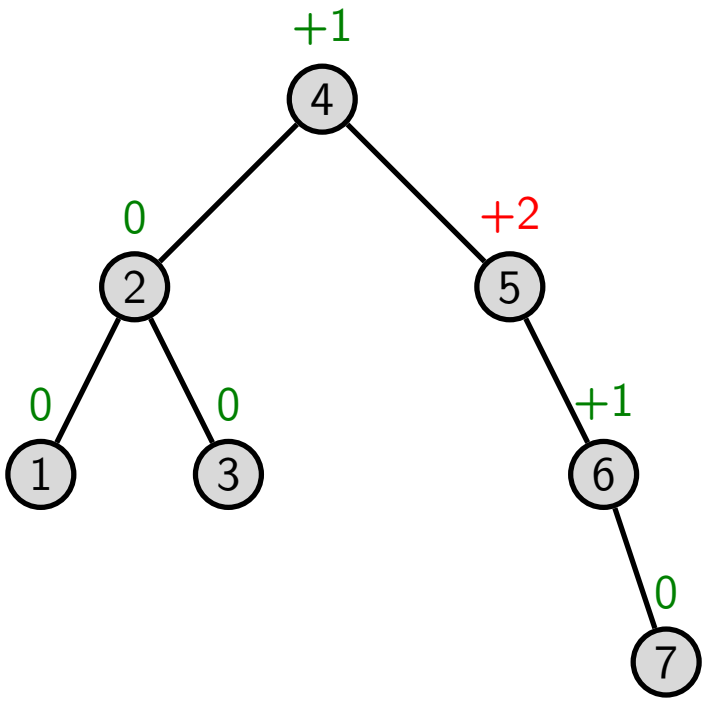
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, 7, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

7 Ekle

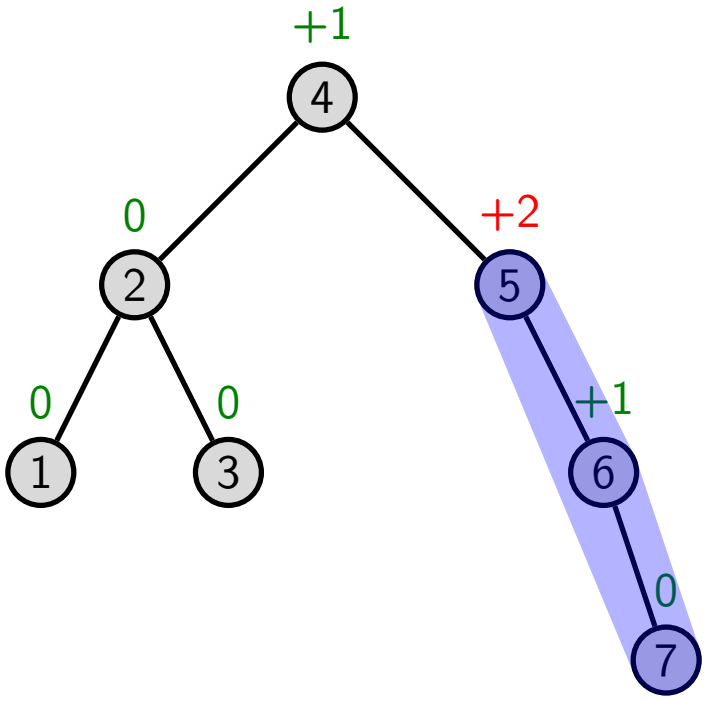
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

7 Ekle

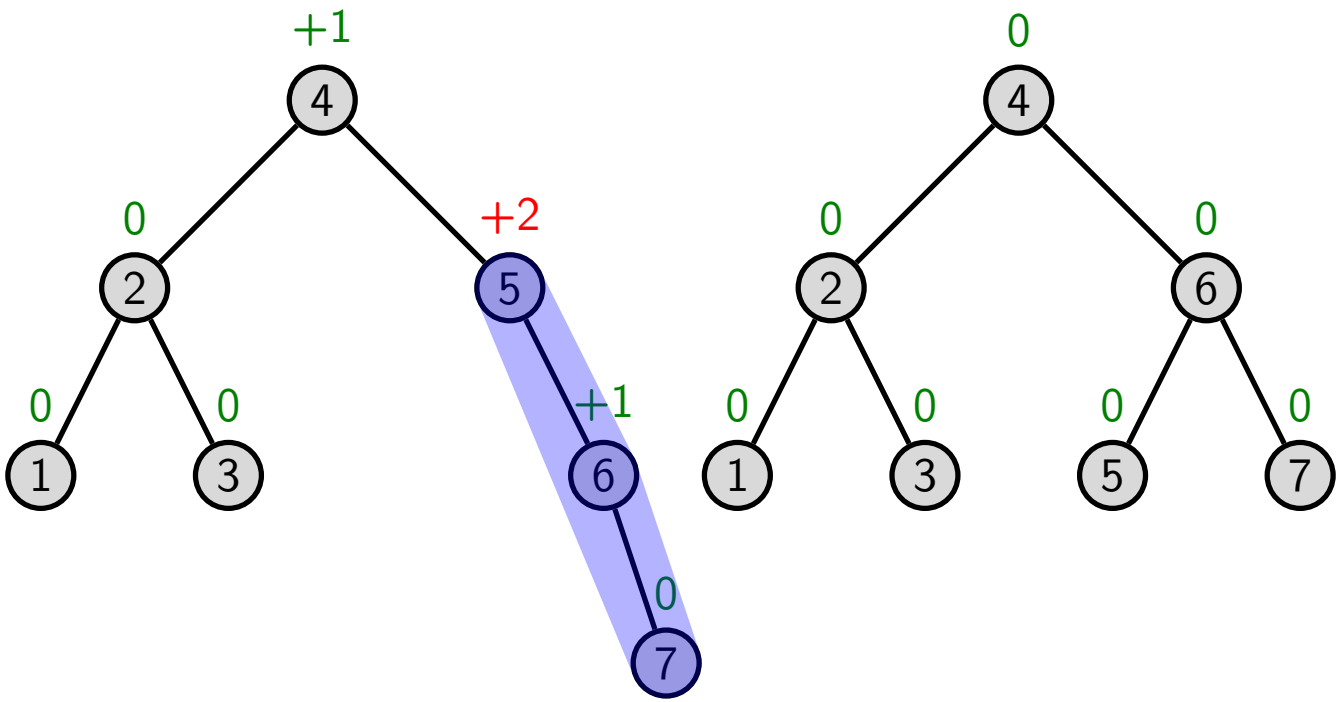
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

7 Ekle

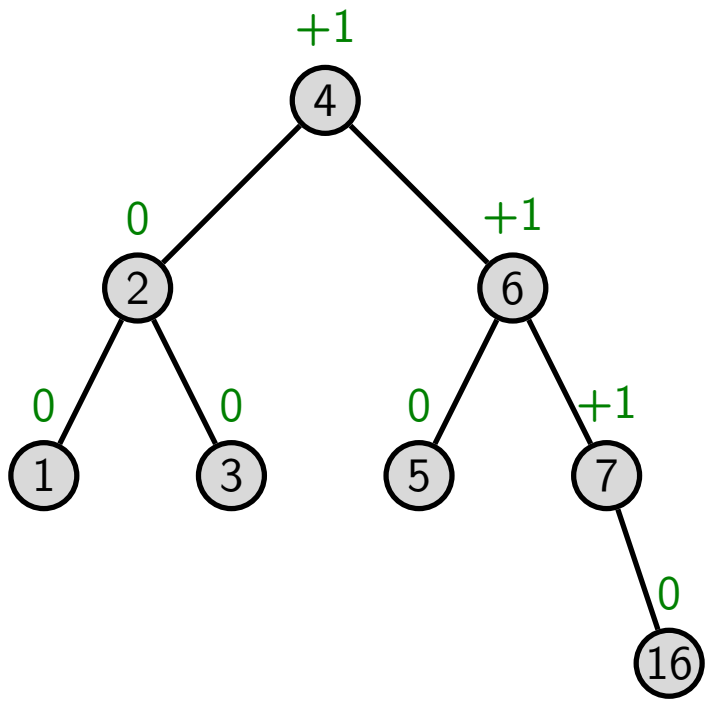
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, 16, 15, 14, 13, 12, 11, 10, 8, 9



Şekil: Sola döndür

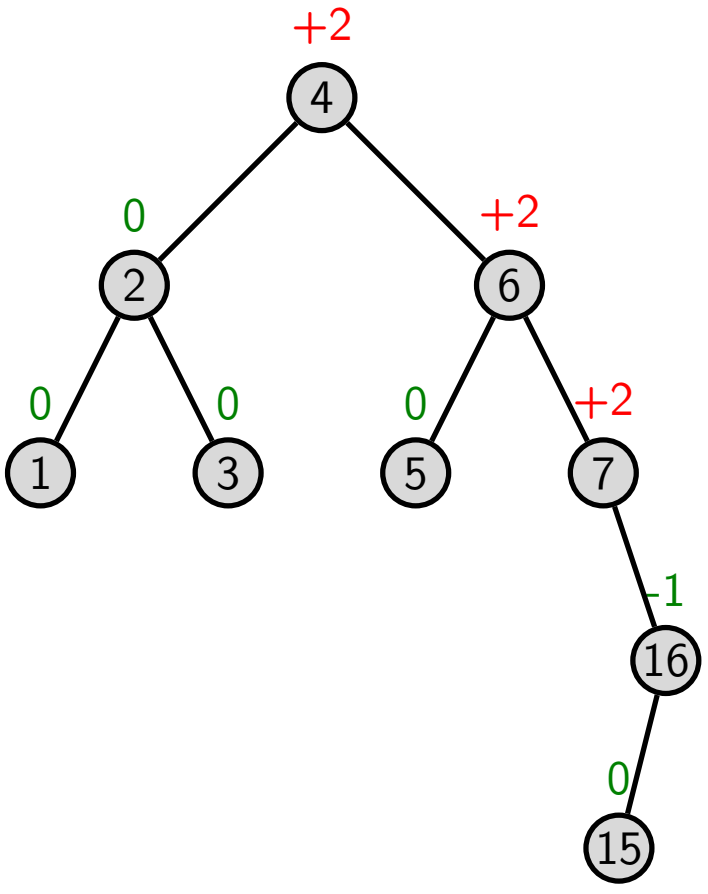
16 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, 15, 14, 13, 12, 11, 10, 8, 9



15 Ekle

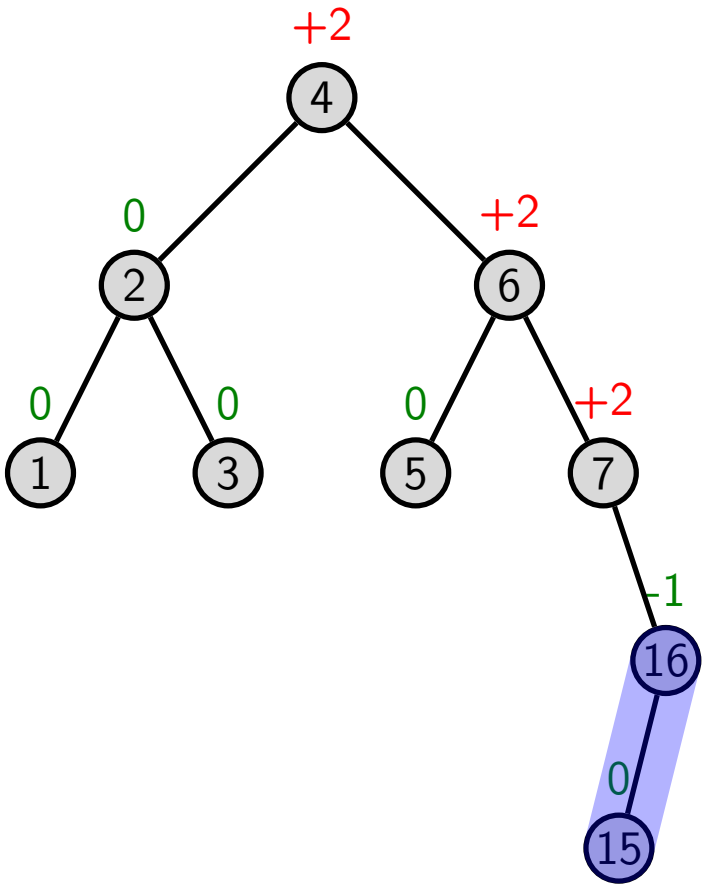
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, 14, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

15 Ekle

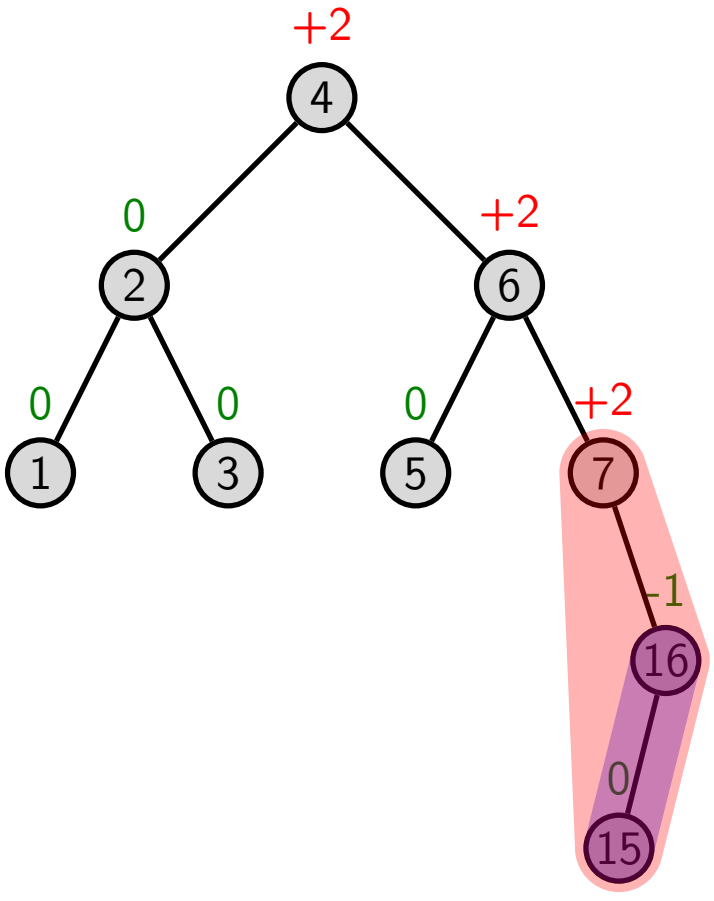
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, 14, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

15 Ekle

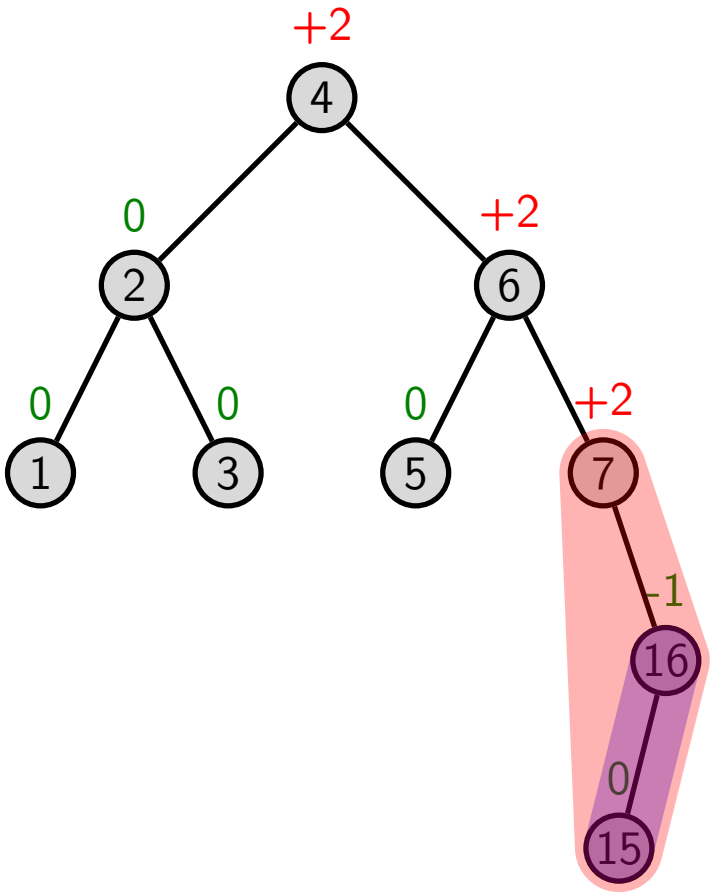
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, 14, 13, 12, 11, 10, 8, 9

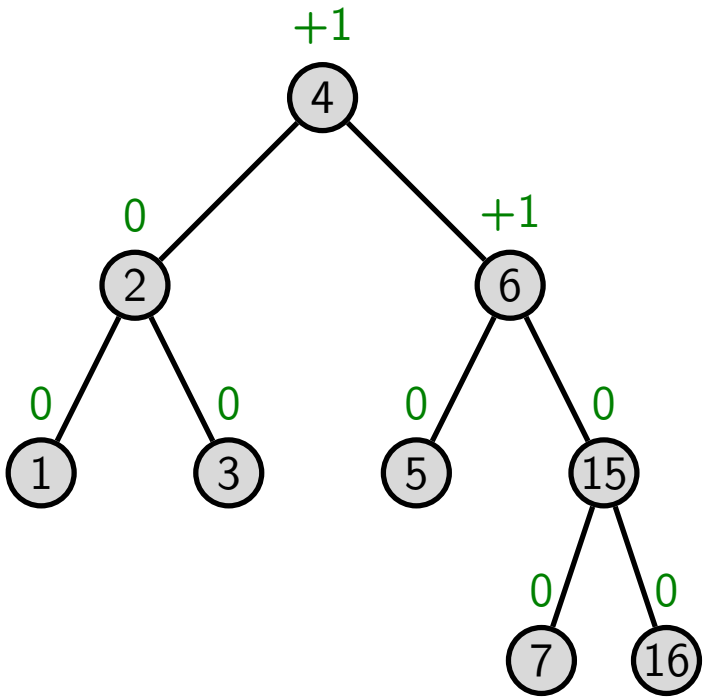


Şekil: Mavi sağa, sonra kırmızı sola

15 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, 14, 13, 12, 11, 10, 8, 9

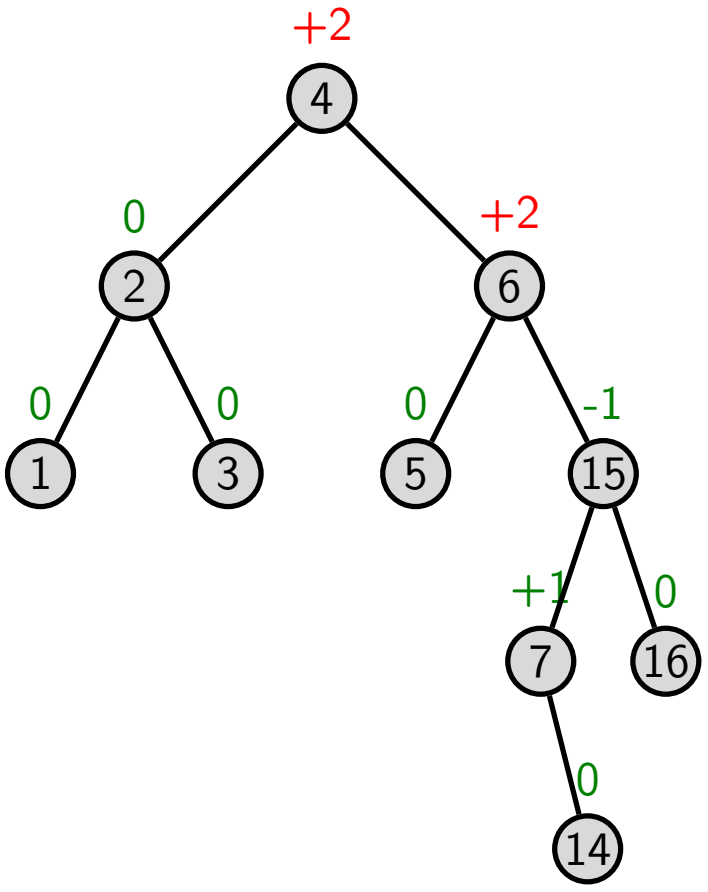




Şekil: Mavi sağa, sonra kırmızı sola

14 Ekle

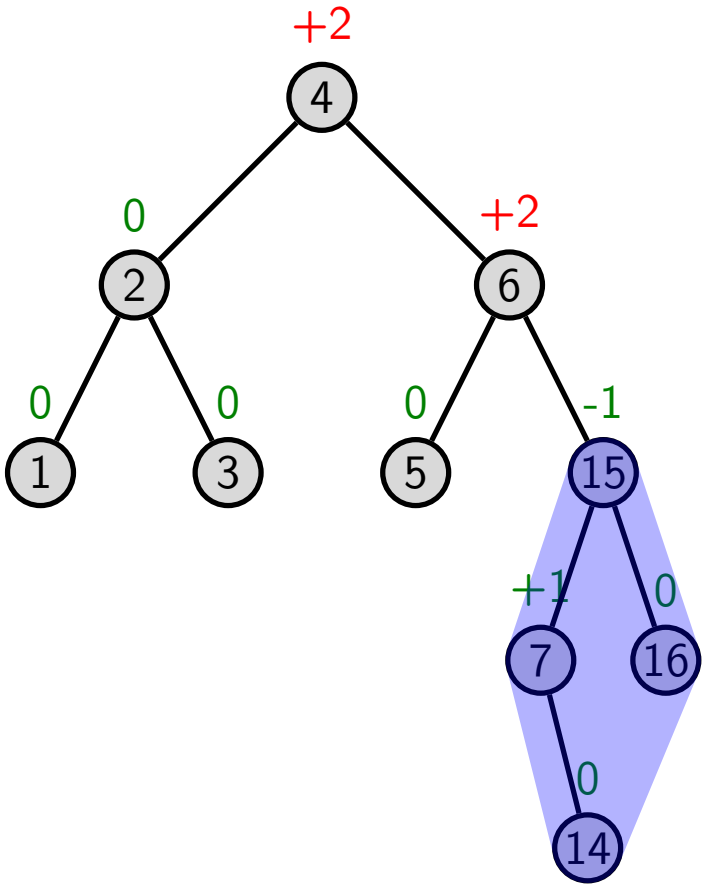
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

14 Ekle

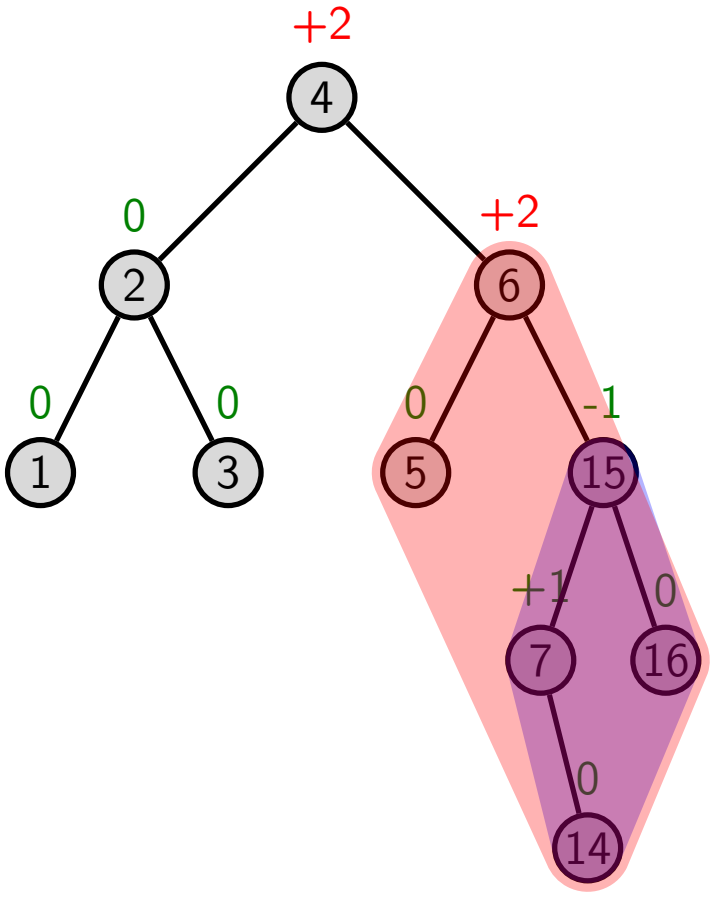
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

14 Ekle

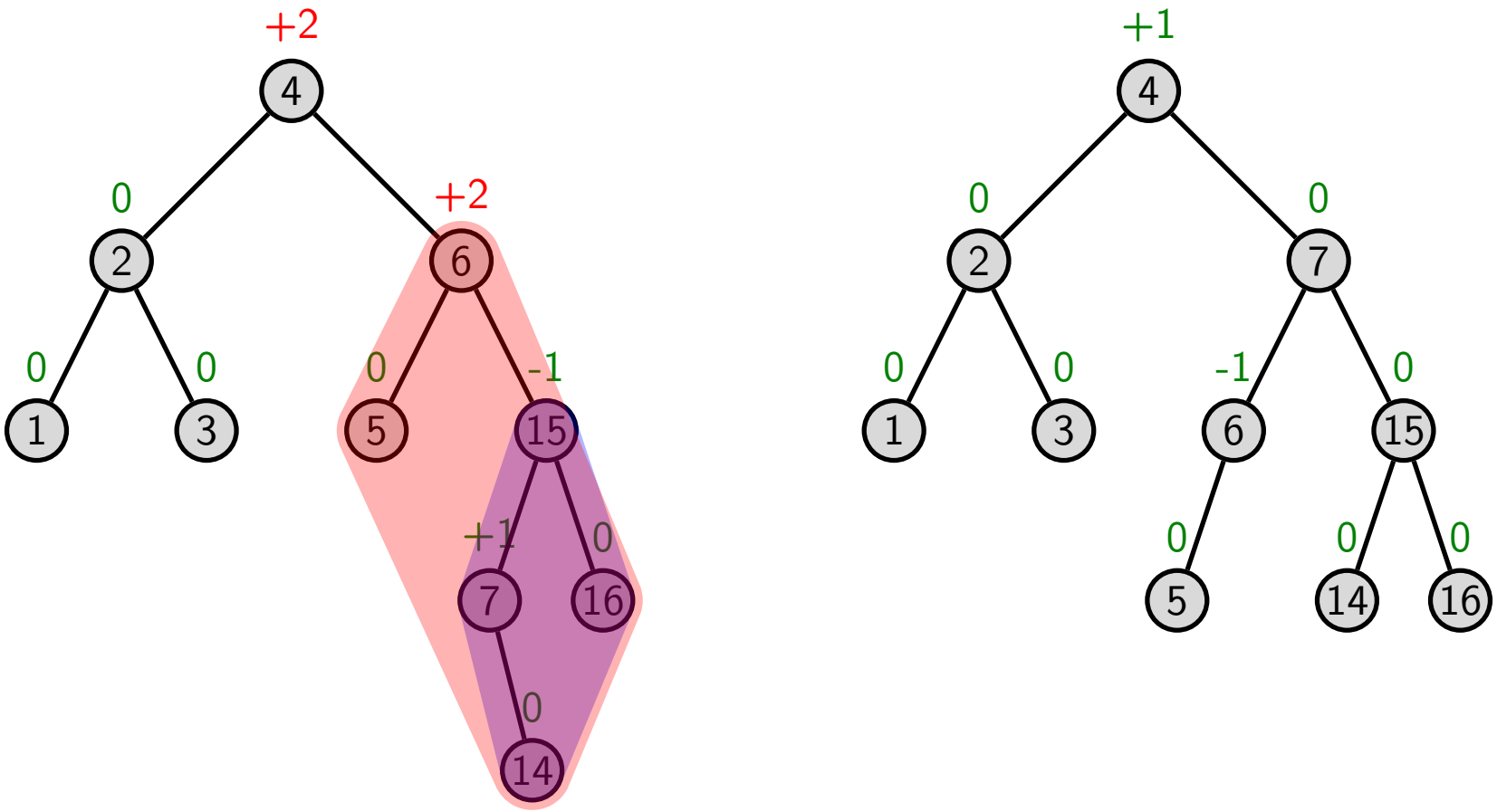
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

14 Ekle

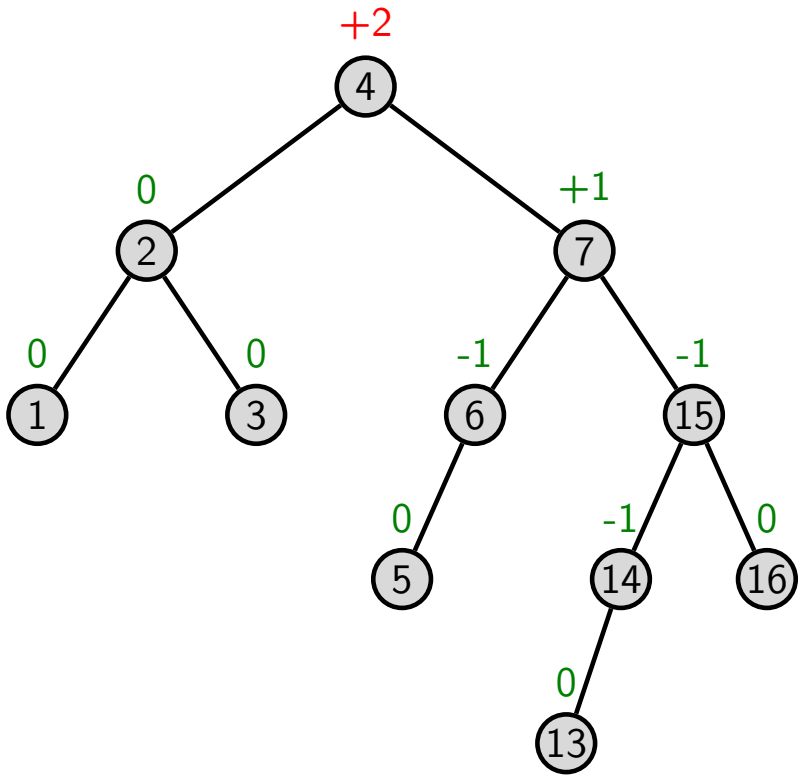
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, 13, 12, 11, 10, 8, 9



Şekil: Mavi sağa, sonra kırmızı sola

13 Ekle

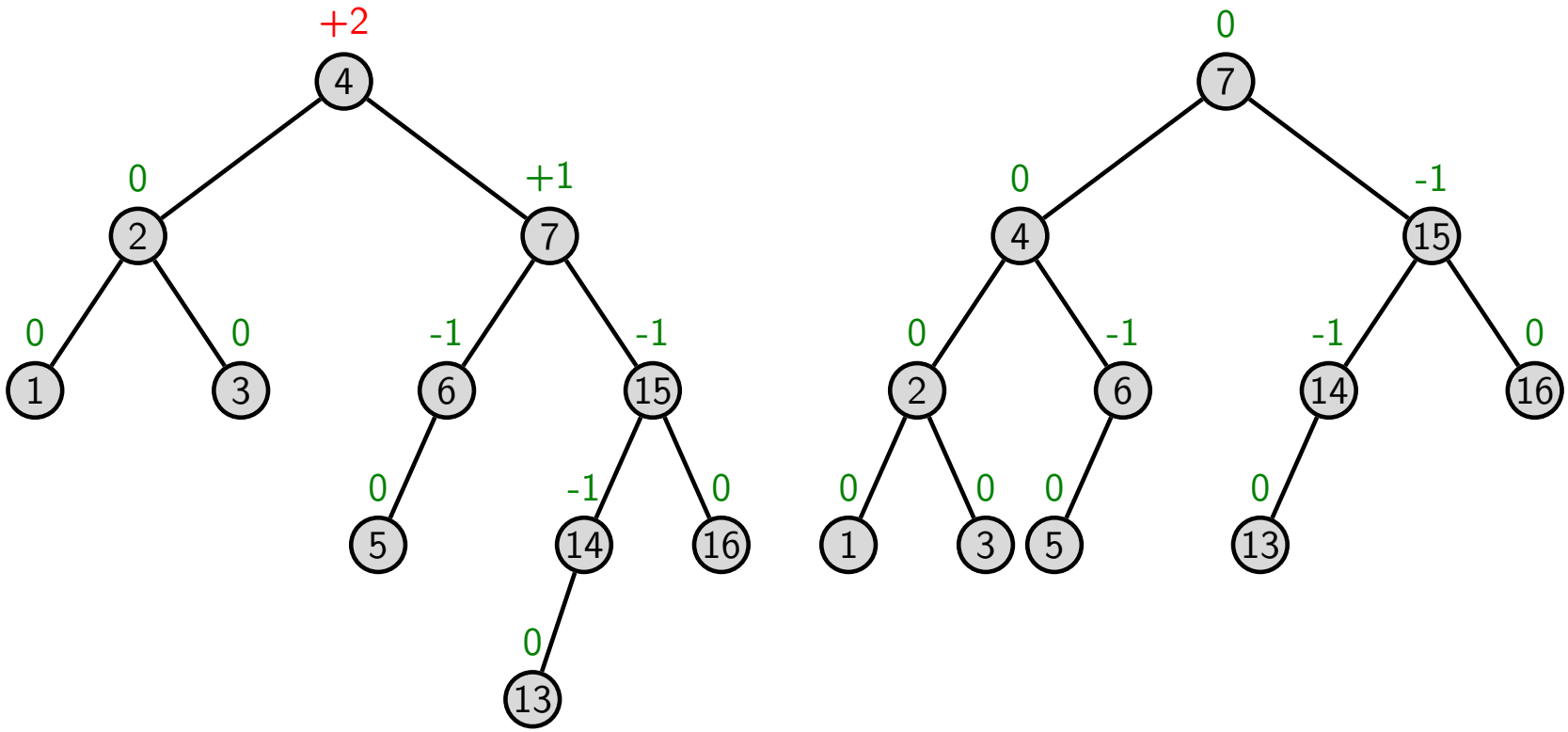
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, 12, 11, 10, 8, 9



Şekil: Tüm ağacı sola döndür

13 Ekle

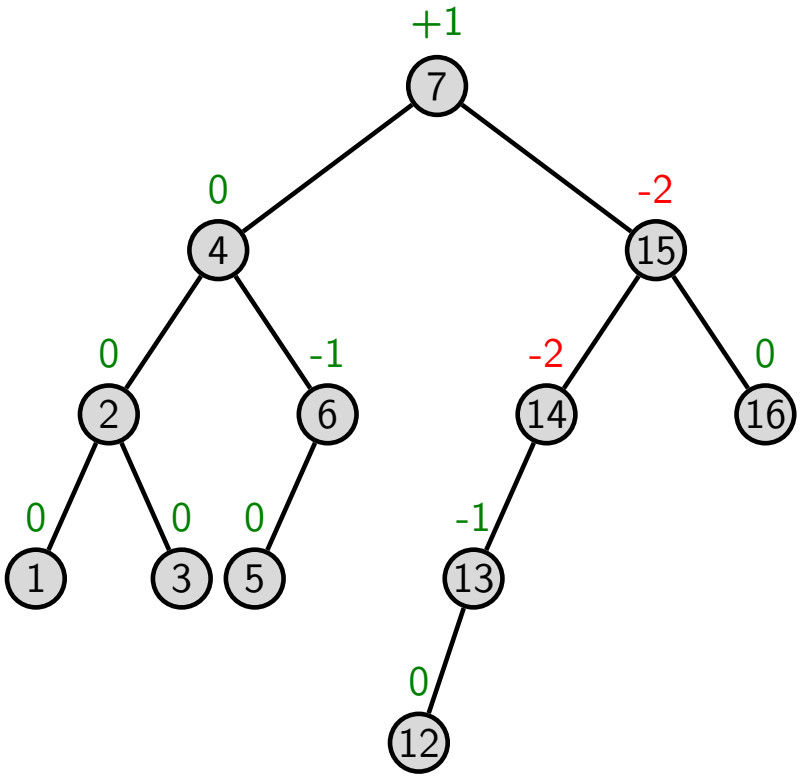
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, 12, 11, 10, 8, 9



Şekil: Tüm ağacı sola döndür

12 Ekle

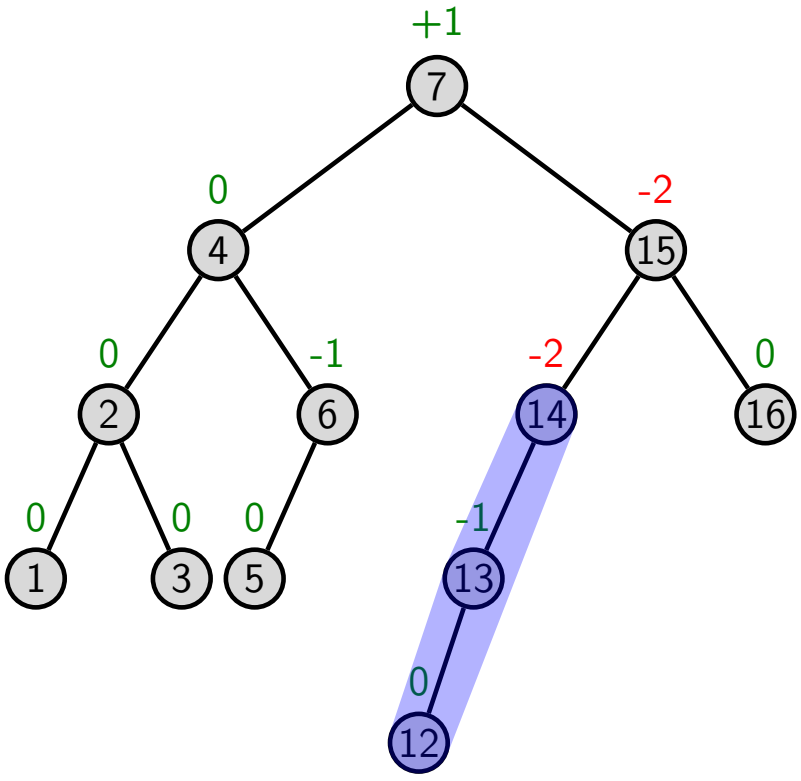
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, 11, 10, 8, 9



Şekil: Sağa döndür

12 Ekle

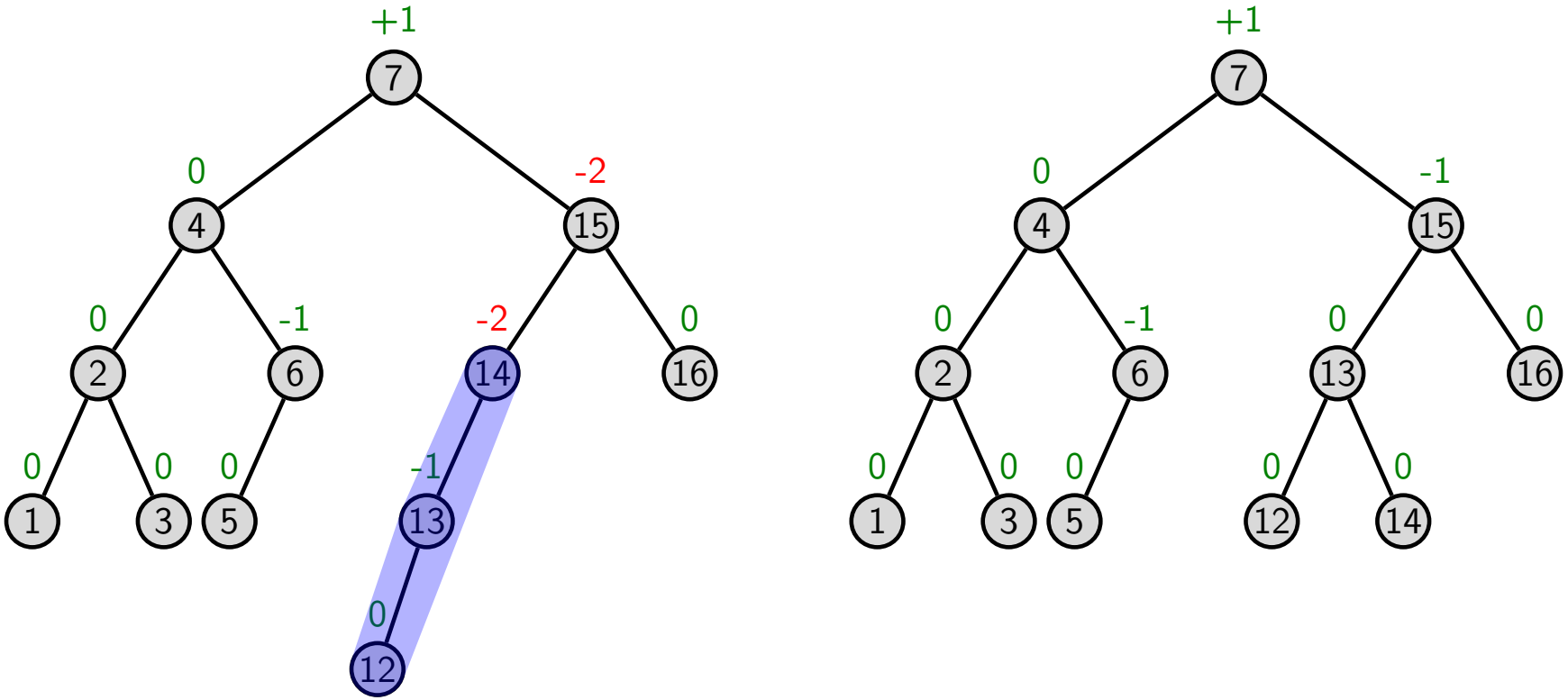
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, 11, 10, 8, 9



Şekil: Sağa döndür

12 Ekle

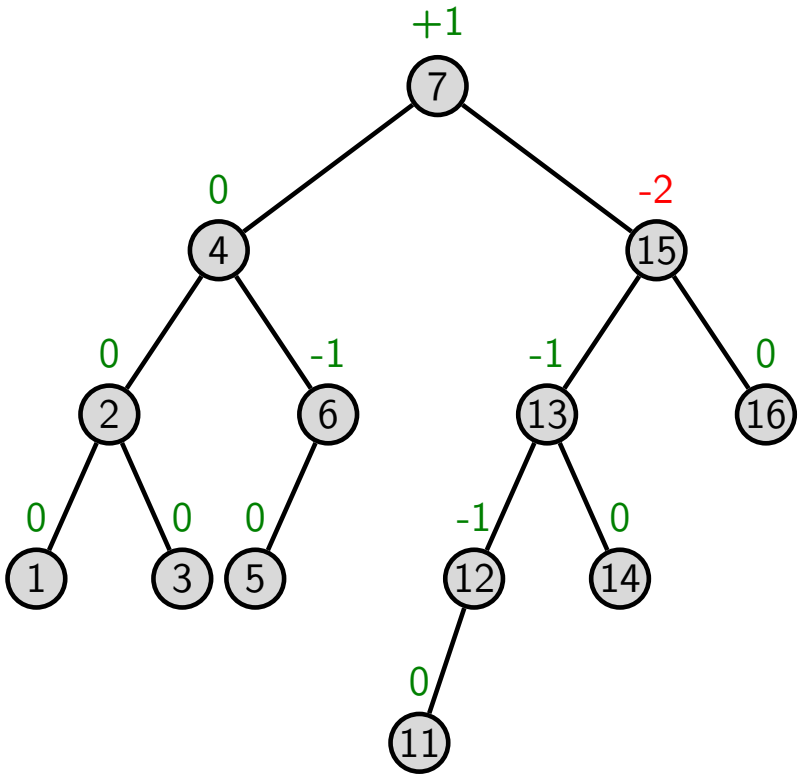
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, 11, 10, 8, 9



Şekil: Sağa döndür

11 Ekle

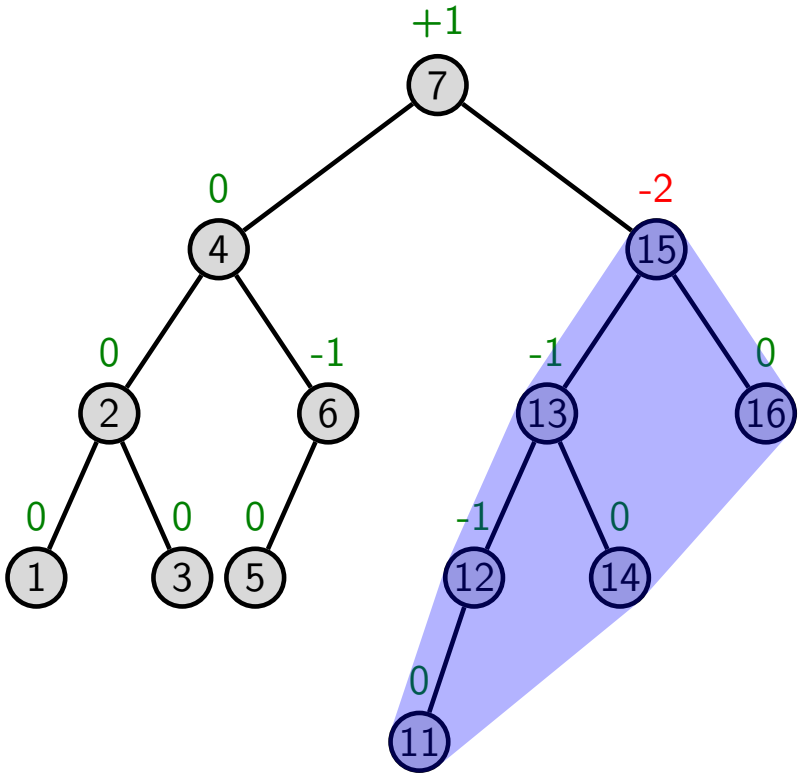
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, 10, 8, 9



Şekil: Sağa döndür

11 Ekle

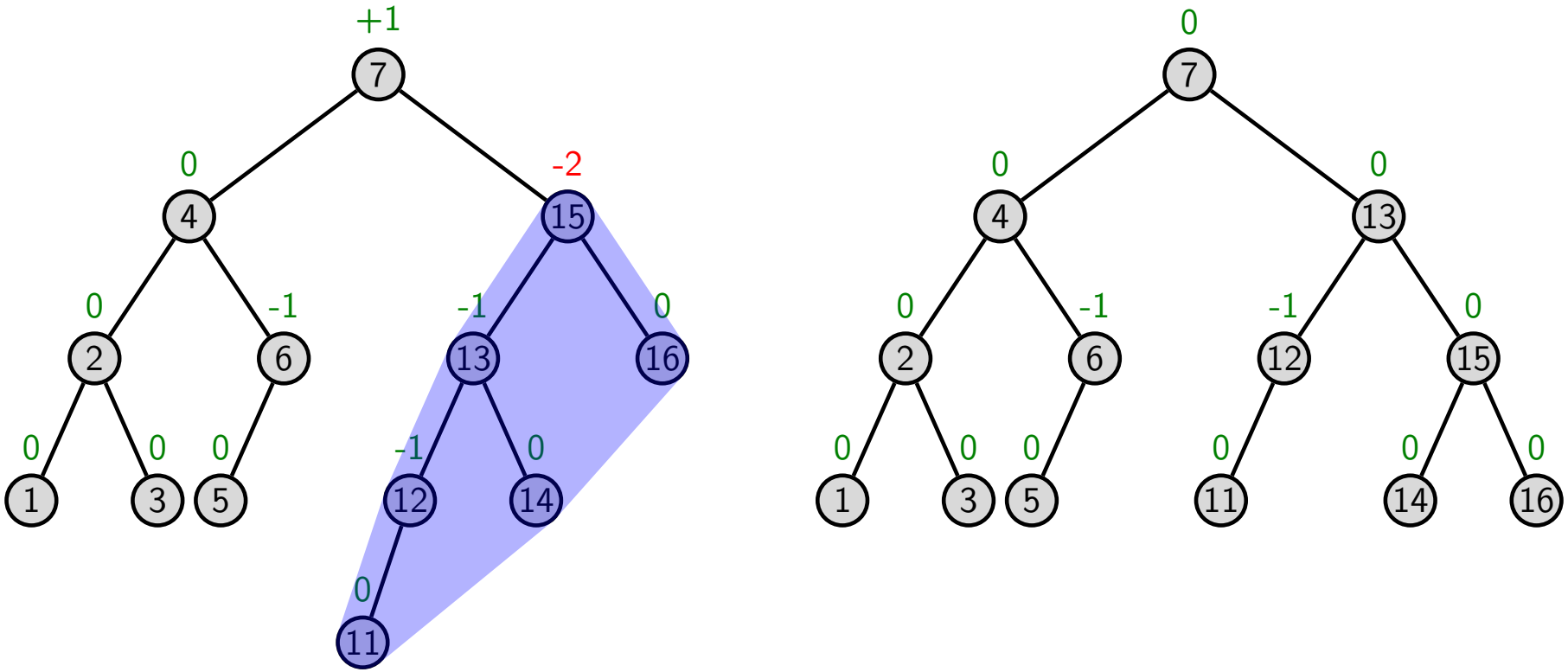
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, 10, 8, 9



Şekil: Sağa döndür

11 Ekle

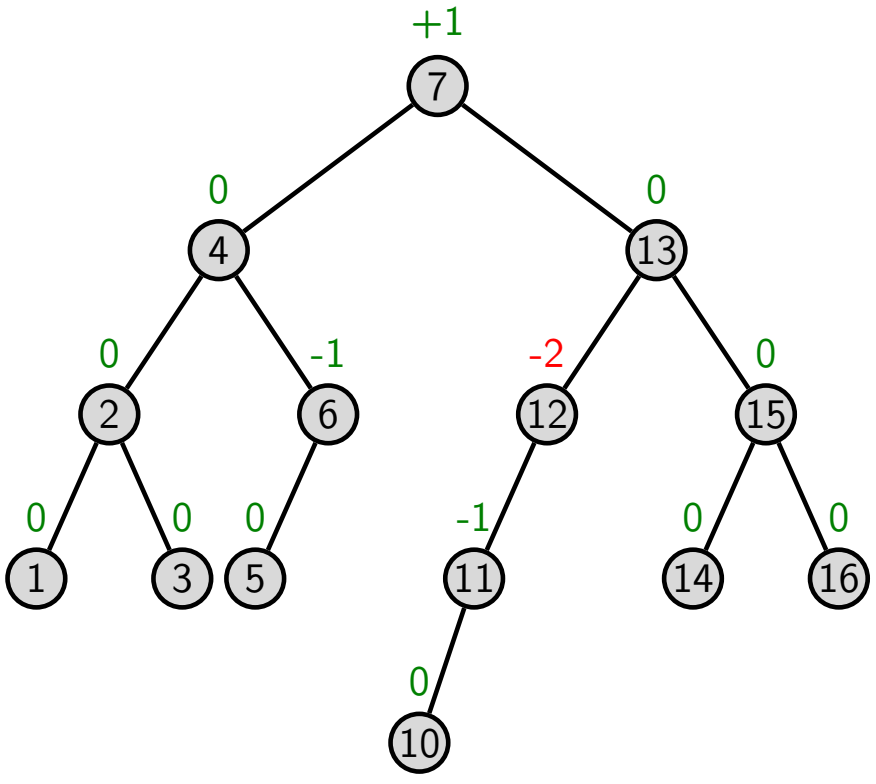
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, 10, 8, 9



Şekil: Sağa döndür

10 Ekle

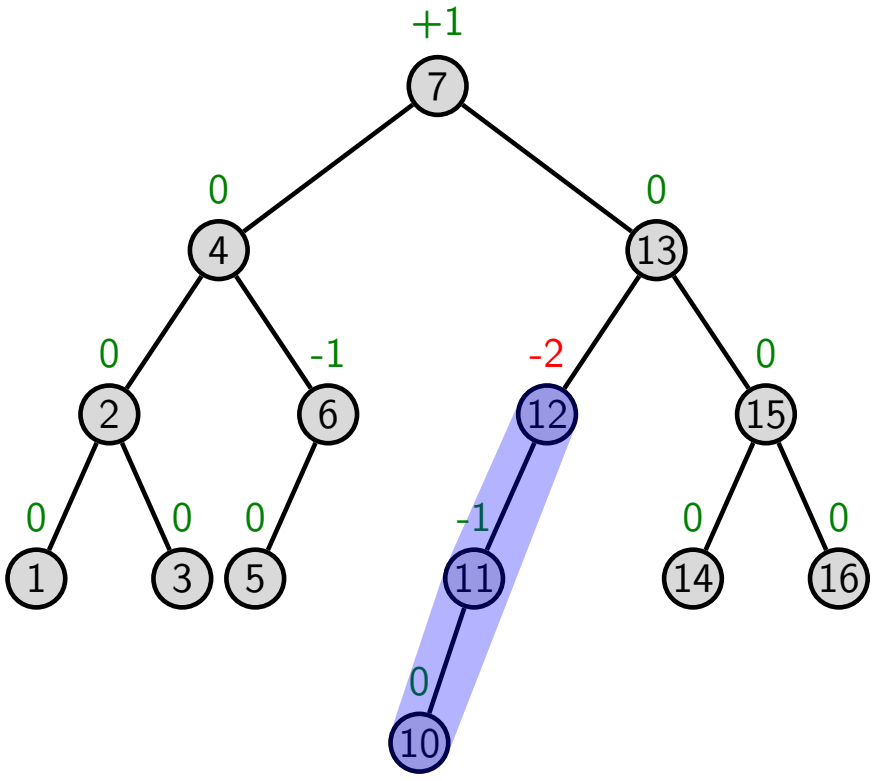
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, 8, 9



Şekil: Sağa döndür

10 Ekle

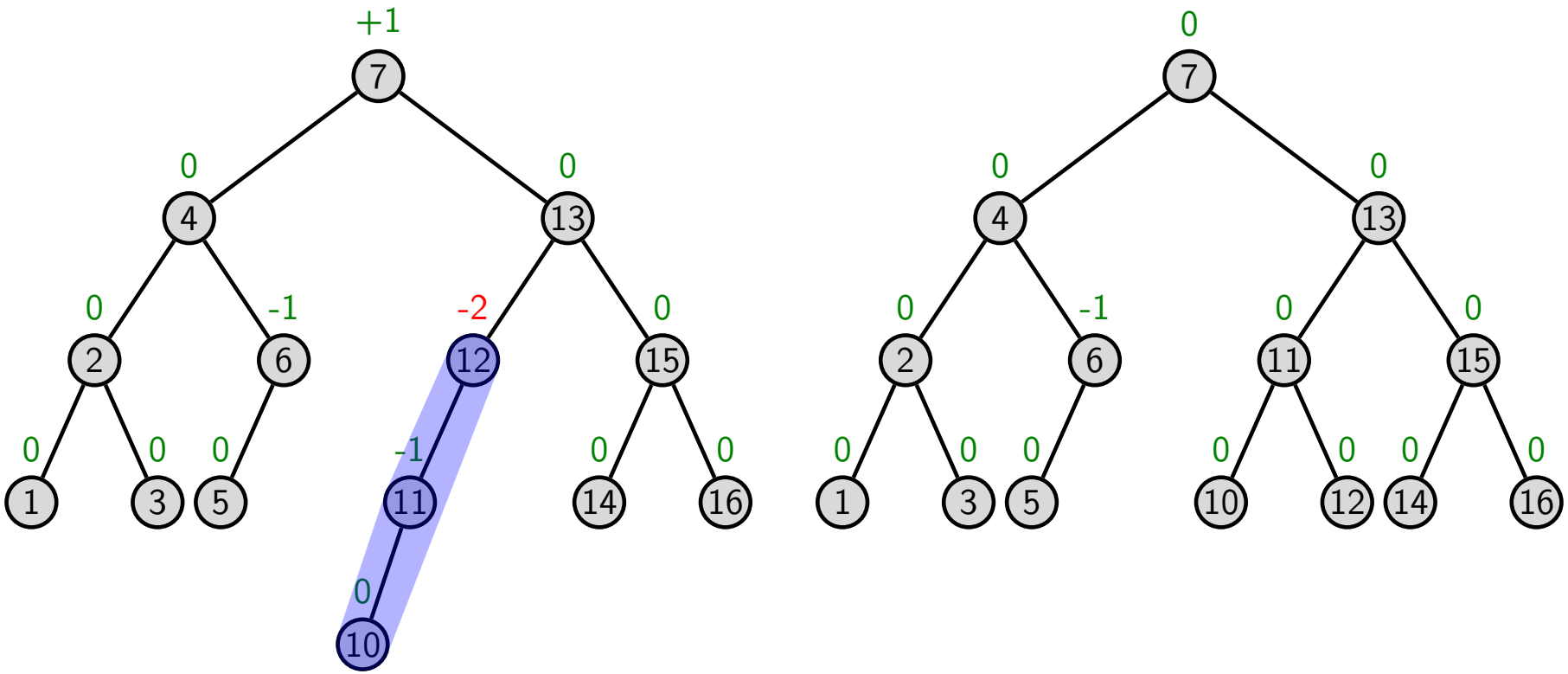
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, 8, 9



Şekil: Sağa döndür

10 Ekle

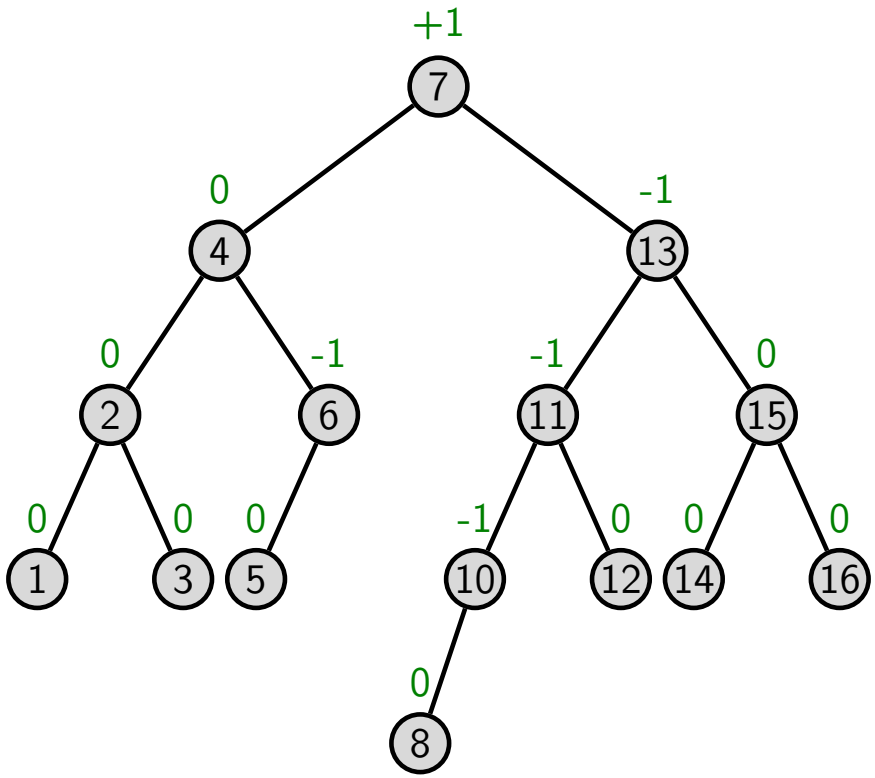
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, 8, 9



Şekil: Sağa döndür

8 Ekle

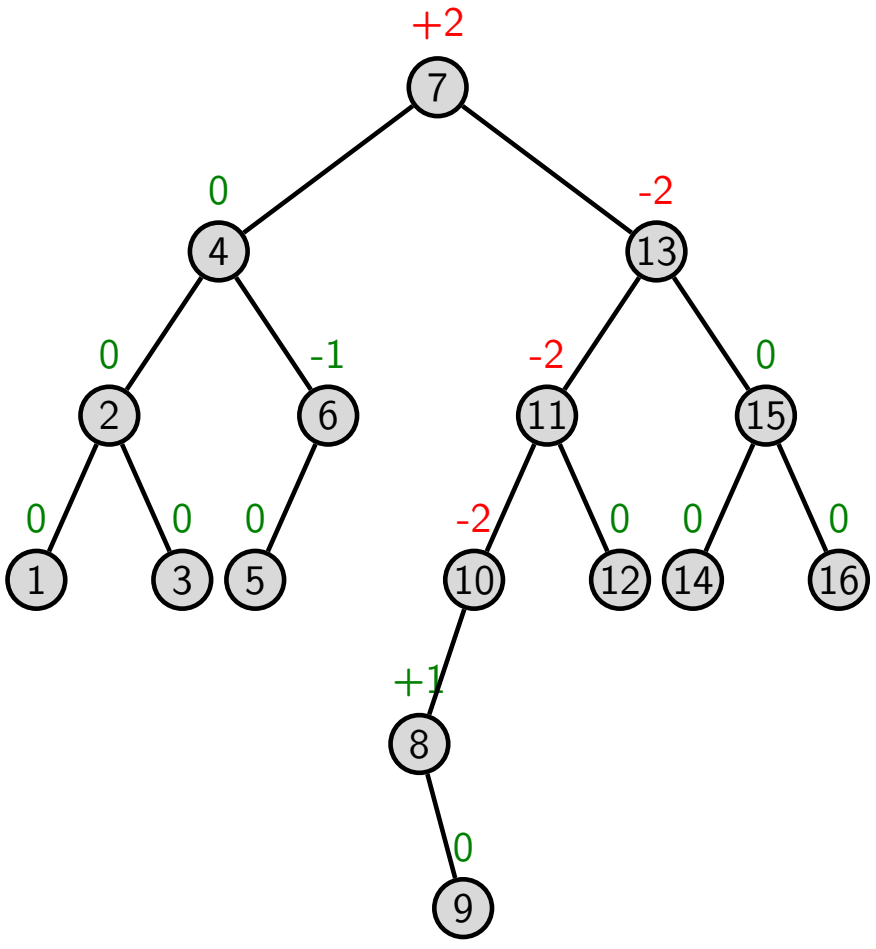
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, ~~8~~, 9



Şekil: Sağa döndür

9 Ekle

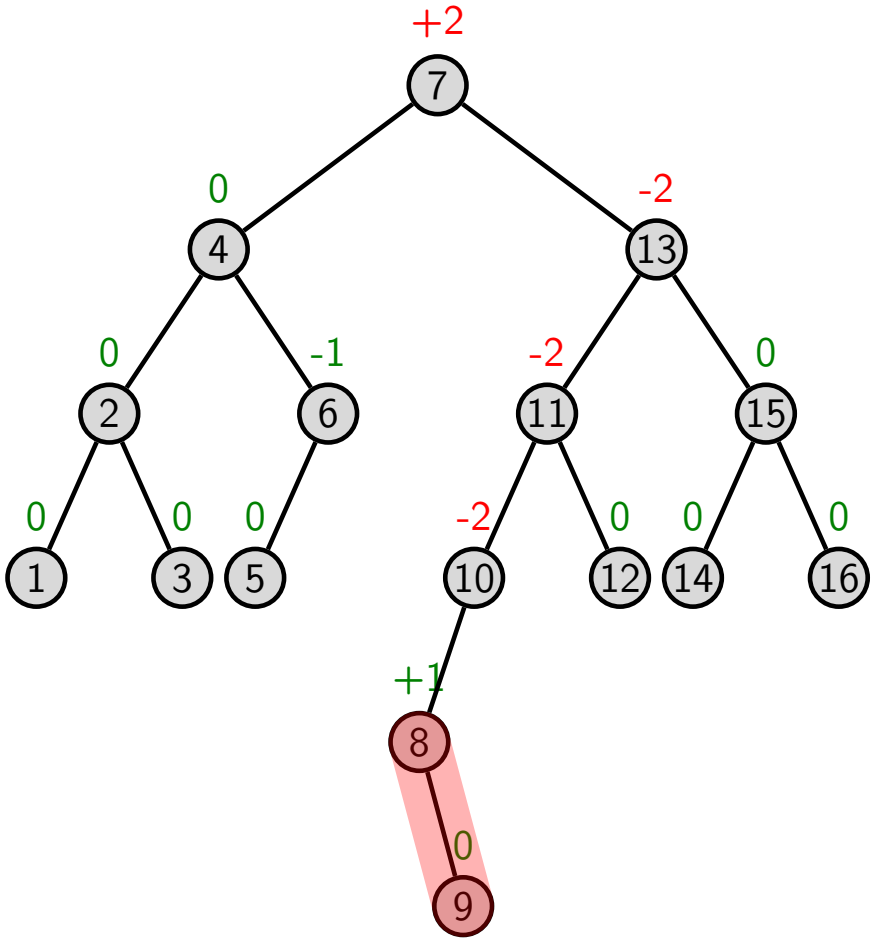
Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, ~~8~~, ~~9~~



Şekil: Kırmızı sola, mavi sağa

9 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, ~~8~~, ~~9~~



Şekil: Kırmızı sola, mavi sağa

9 Ekle

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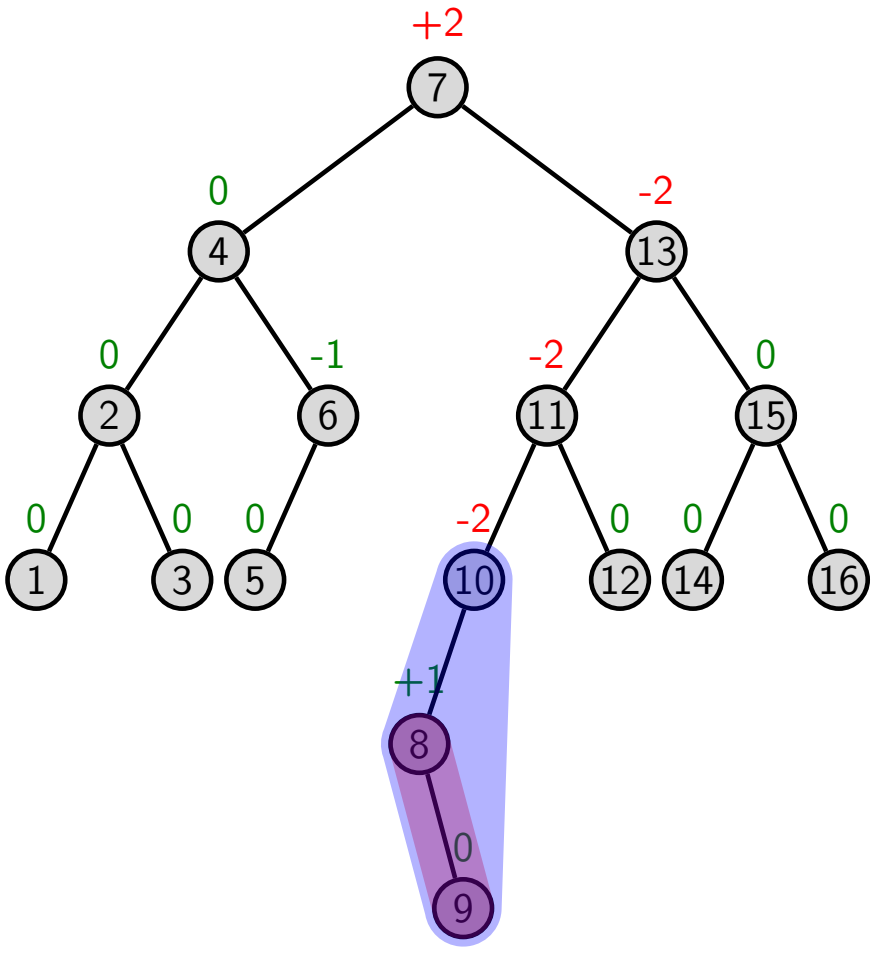
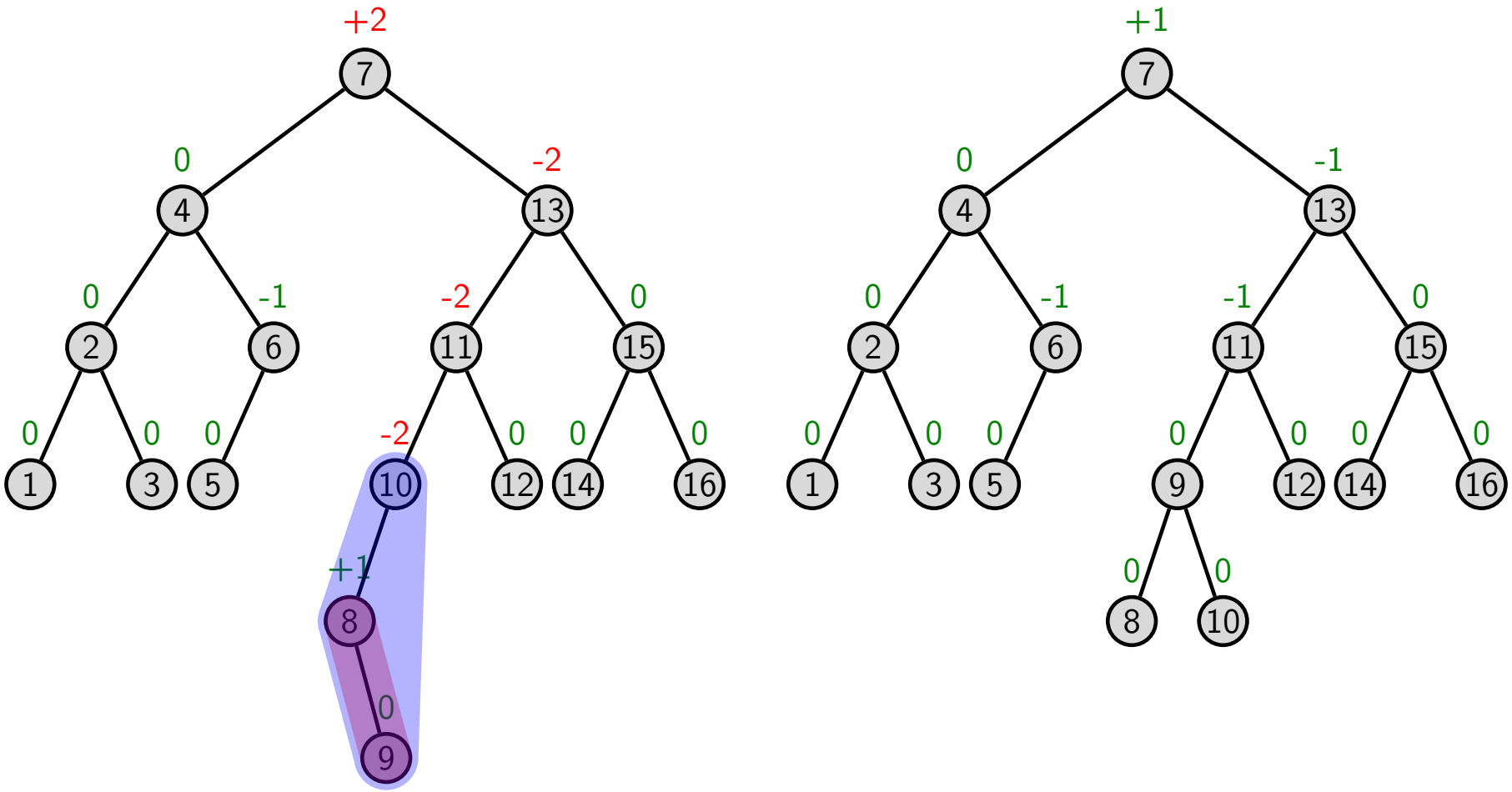


Şekil: Kırmızı sola, mavi sağa

9 Ekle

Eklenecek: ~~3~~, ~~2~~, ~~1~~, ~~4~~, ~~5~~, ~~6~~, ~~7~~, ~~16~~, ~~15~~, ~~14~~, ~~13~~, ~~12~~, ~~11~~, ~~10~~, ~~8~~, ~~9~~



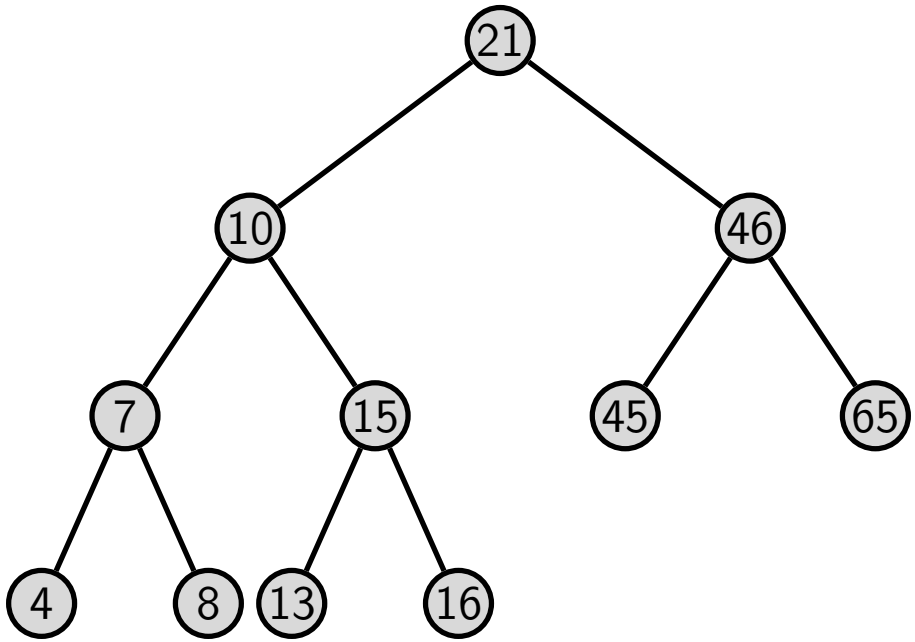
Şekil: Kırmızı sola, mavi sağa

Soru

13, 21, 45, 8, 10, 65, 7, 4, 16, 46, 15 değerlerini sırasıyla AVL ağacına ekleyin.

Soru

13, 21, 45, 8, 10, 65, 7, 4, 16, 46, 15 değerlerini sırasıyla AVL ağacına ekleyin.

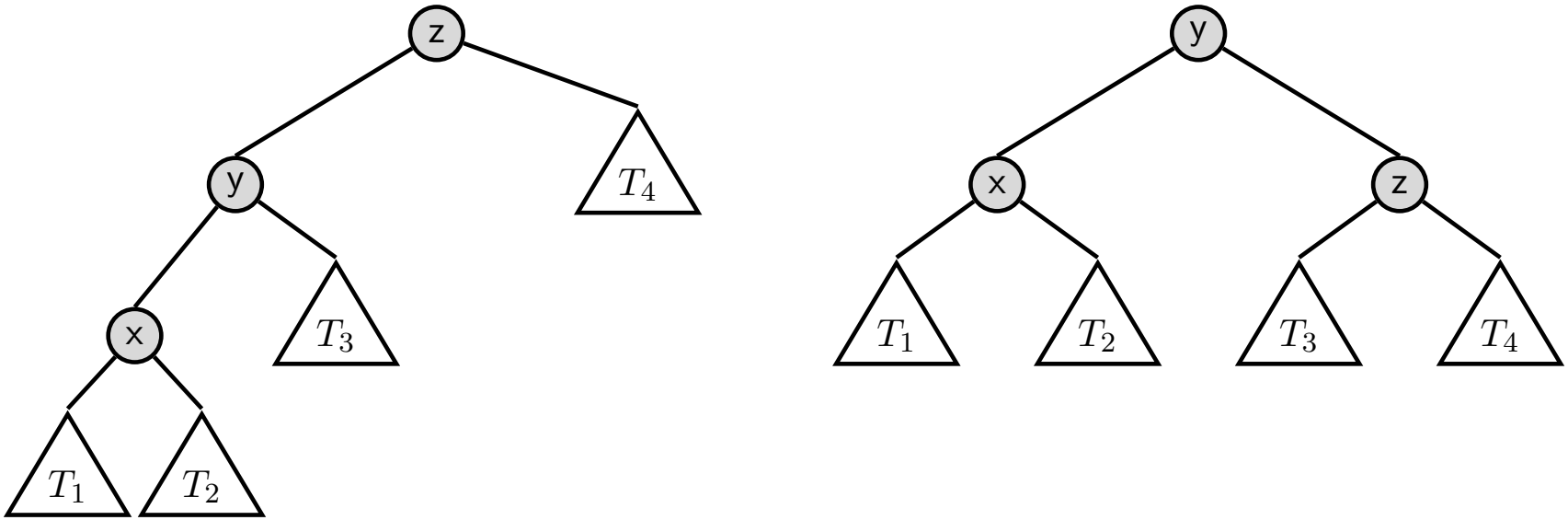


Şekil: Değerler eklenince ortaya çıkan AVL Ağacı

Silme İşlemi

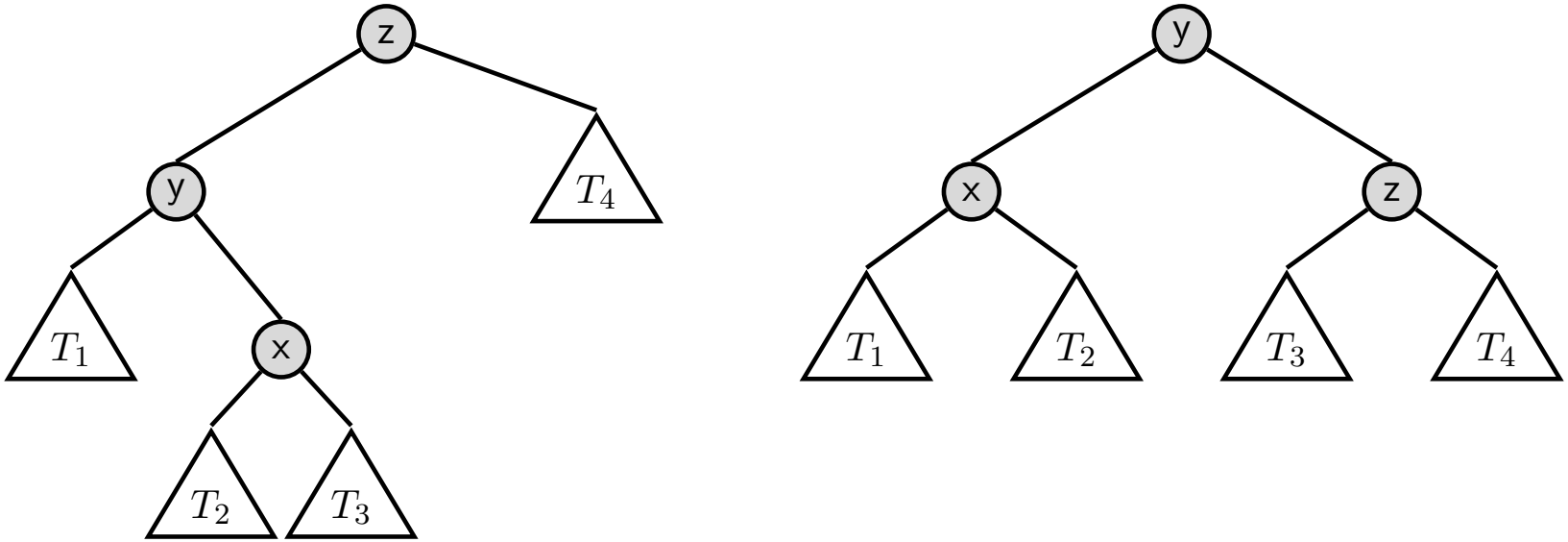
- Silinecek düğüm w olsun
- w düğümünü ikili arama ağacındaki gibi sil
- w'dan köke doğru ilk dengesiz z düğümünü bul
- y, z'nin yüksek çocuğu olsun
- x, y'nin yüksek çocuğu olsun
- 4 farklı durum ortaya çıkmaktadır

Sol'un solu durumu



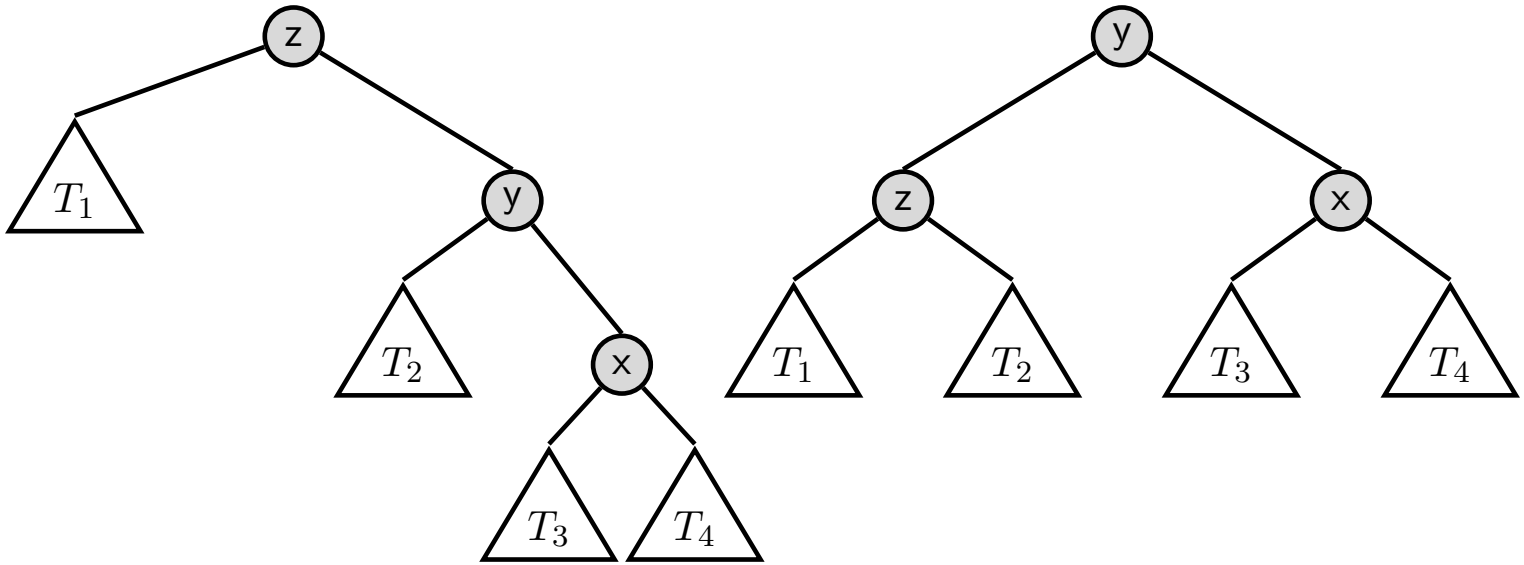
Şekil: Sağa döndürme

Sol'un sağı durumu



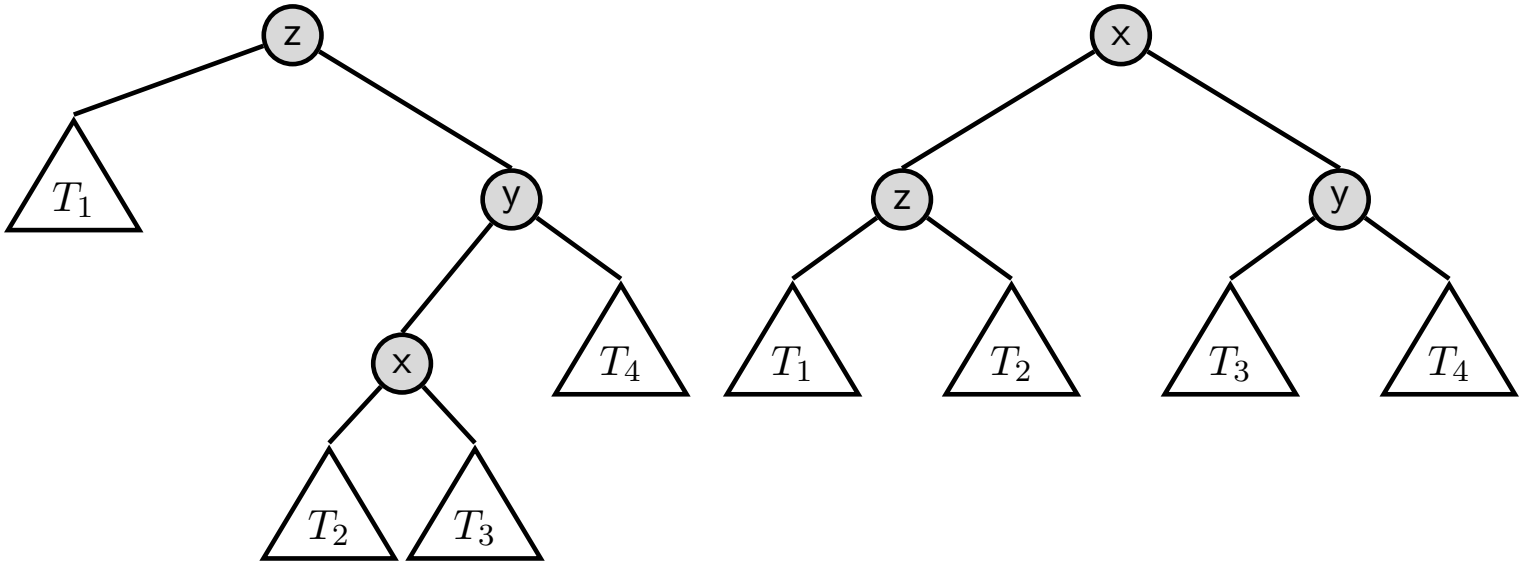
Şekil: Önce sola sonra sağa döndürme

Sağ'ın sağı durumu



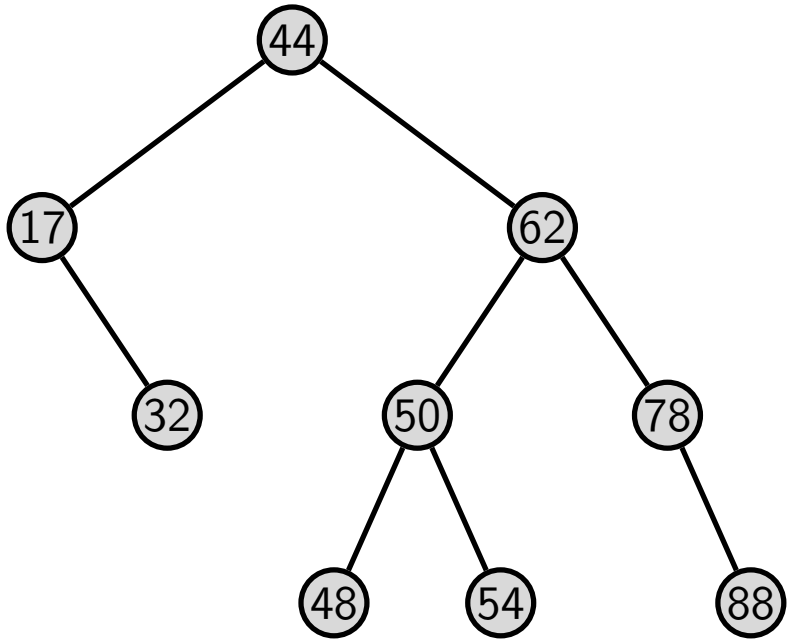
Şekil: Sola döndürme

Sağ'ın solu durumu

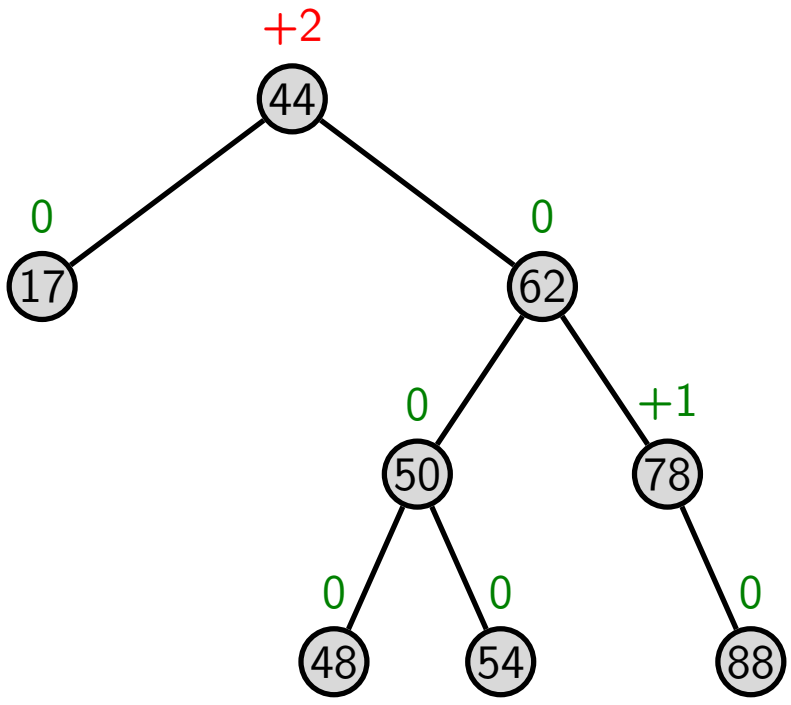


Şekil: Önce sağa sonra sola döndürme

Örnek: 32'nin silinmesi

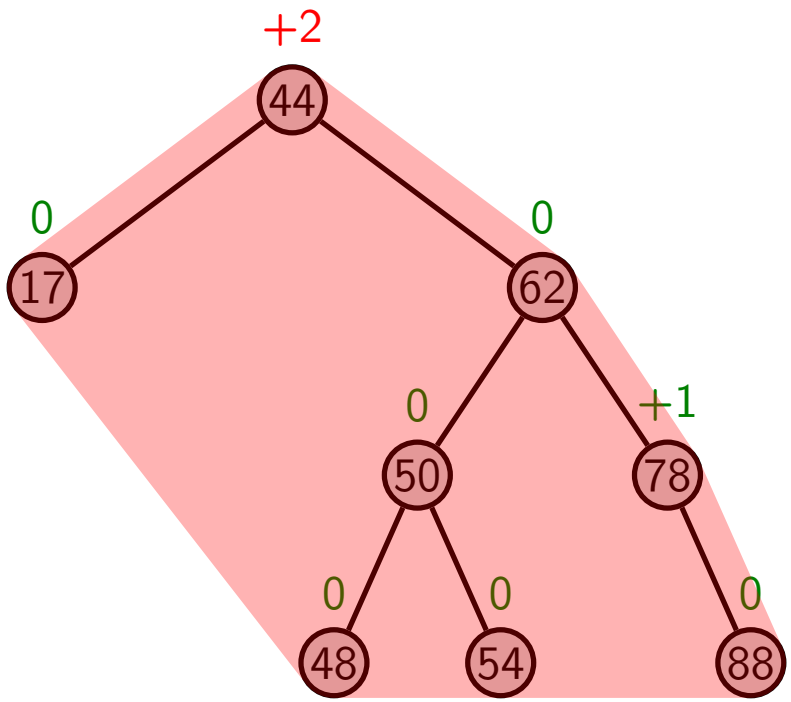


Örnek: 32'nin silinmesi



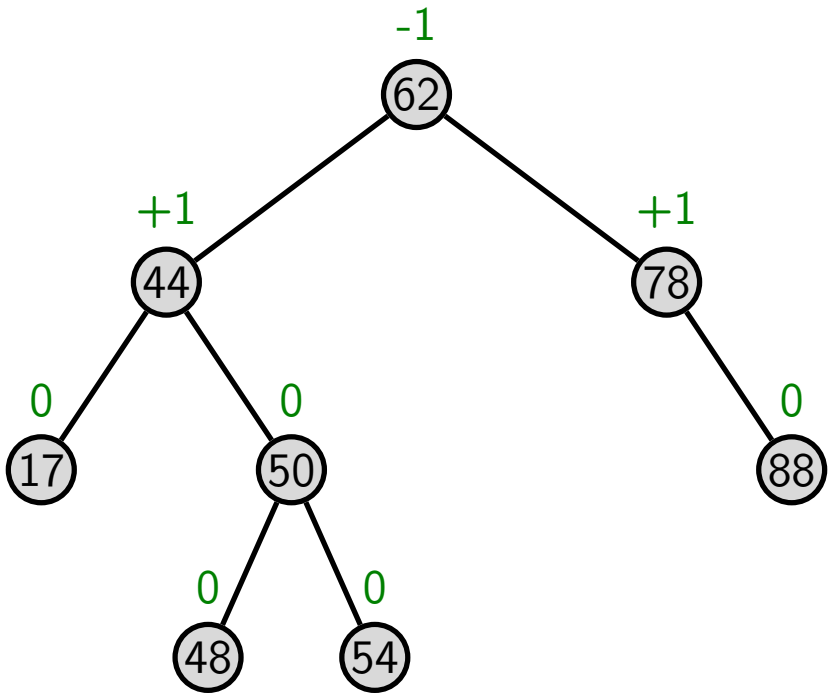
Şekil: Sola döndürme

Örnek: 32'nin silinmesi



Şekil: Sola döndürme

Örnek: 32'nin silinmesi



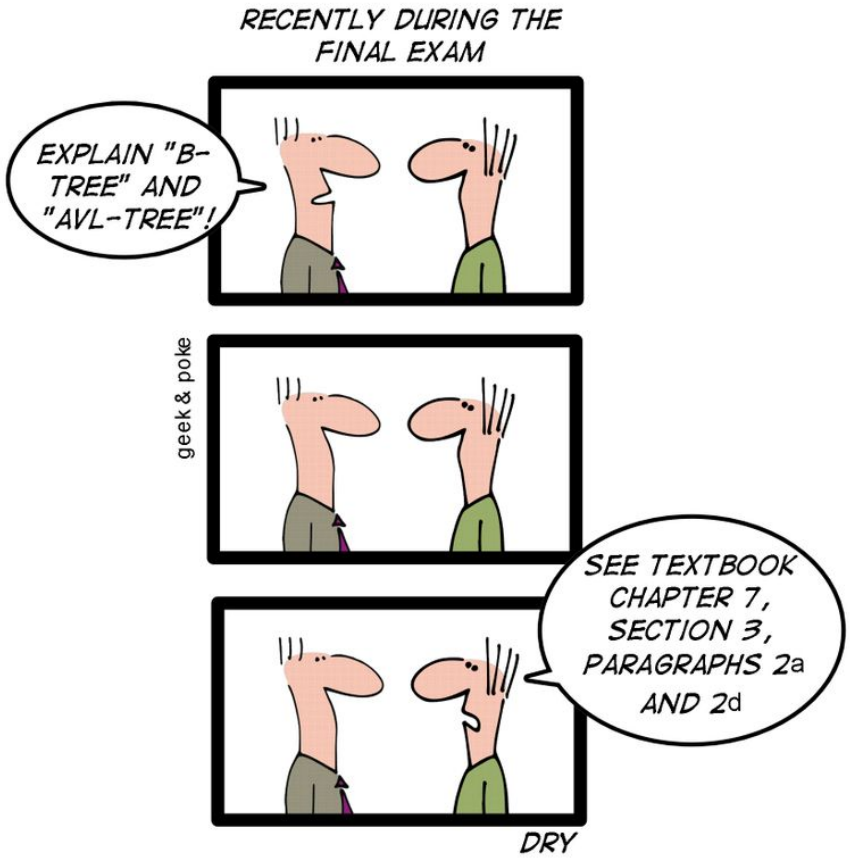
Şekil: 32 silindikten sonra ağaç dengelendi

Görselleştirme

- https://www.cs.usfca.edu/~galles/visualization/AVLtree.html
- https://visualgo.net/bn/bst

THE MAIN PRINCIPLES OF SOFTWARE ENGINEERING

PART 1



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