



# Bölüm 10: Arama Ağaçları

## Veri Yapıları



# Arama Ağacı

- Her düğüm, belirli bir öğeyi temsil eder.
- Her öğenin bir anahtar değeri vardır.
- Öğeler bu anahtar değerlerine göre bir düzen içinde saklanırlar.
- Arama işlemi  $O(\log n)$  veya  $O(h)$  zaman karmaşıklığına sahiptir.
- "n" ağaçtaki düğüm sayısını, "h" ise ağacın yüksekliğini temsil eder.



# Temel İşlemler

- **Ekleme (Insertion):** Bir öğeyi ağaca ekler.
- **Arama (Search):** Belirli bir anahtarla öğeyi arar ve döndürür.
- **Silme (Deletion):** Belirli bir anahtara sahip öğeyi ağaçtan çıkarır.
- **Gezinme (Traversal):** Ağaç içindeki öğeleri belirli bir sırayla gezme.

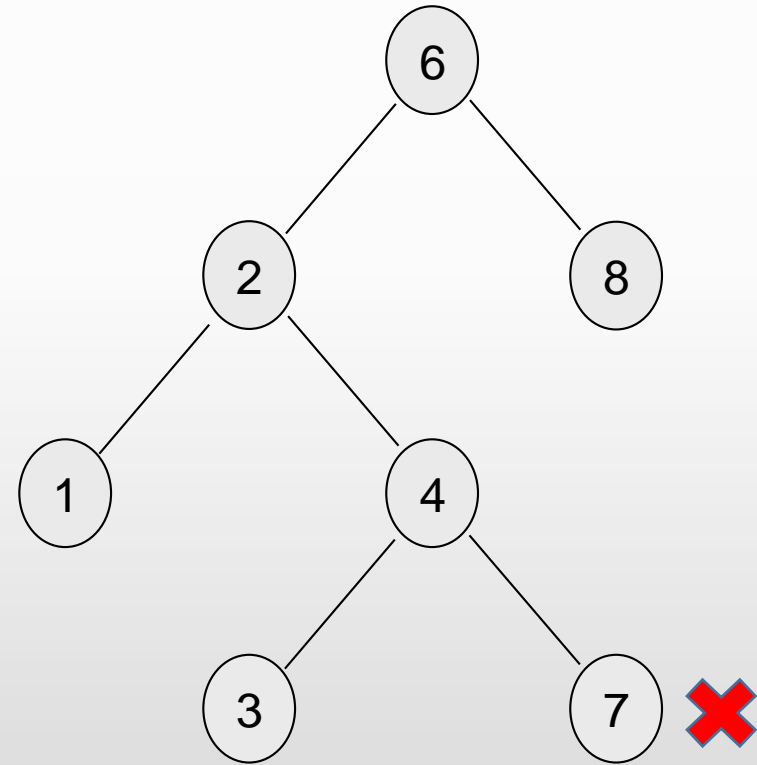
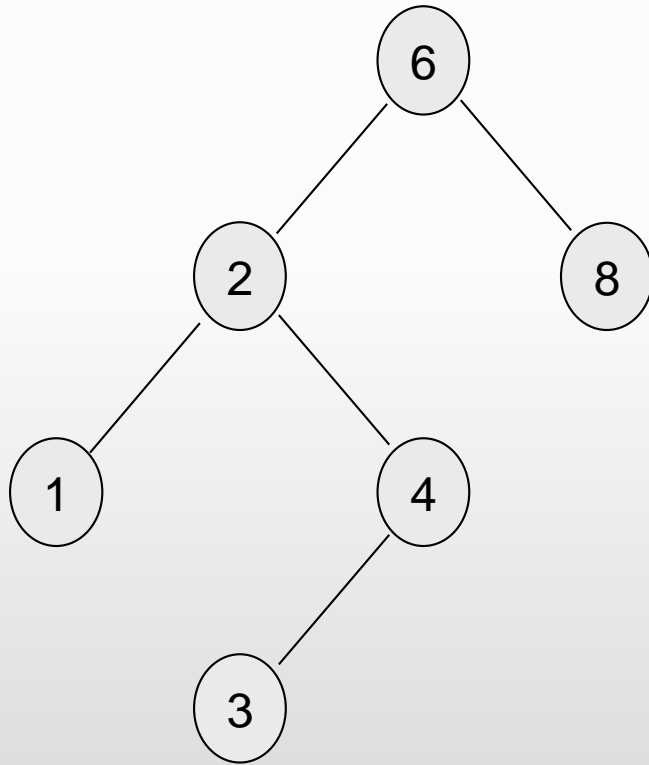


# Arama Ağacı Türleri

- **İkili Arama Ağaçları (Binary Search Trees):** Her düğüm, sol alt ağaçtaki düğümlerden daha büyük ve sağ alt ağaçtaki düğümlerden daha küçük bir anahtarı temsil eder.
- **Kırmızı-Siyah Ağaçlar (Red-Black Trees):** Ağacın yüksekliğini kontrol ederek hızlı arama sağlar.
- **AVL Ağaçları:** Her düğümün iki alt ağacının yükseklik farkı (balance factor) en fazla 1 olan ağaç türü.



# İkili Arama Ağacı





# Kırmızı-Siyah Ağaçlar

- Her düğüm kırmızı veya siyah renkte olabilir.
- Kök düğüm siyah renkte olmalıdır.
- Her yaprak düğümün (NIL düğümleri) siyah olması gerekmektedir.
- Ardışık kırmızı düğümler kabul edilmez.



# AVL Ağacı

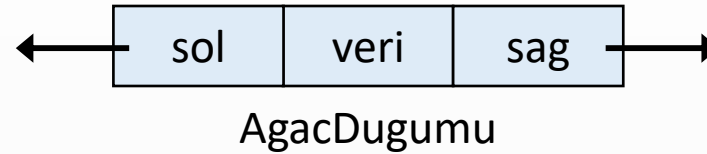
- Her düğümün denge faktörü değeri vardır.
- Denge faktörü, sol ve sağ alt ağaçların yükseklik farkını temsil eder.
- Her düğümün denge faktörü -1, 0 veya 1 olmalıdır.
- Ağaç dengeli olduğunda, her düğümün alt ağaçları da dengelidir.







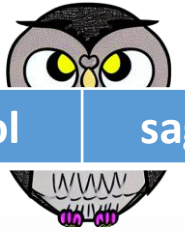
# Ağaç Düğümü Yapısı



```
public class AgacDugumu {  
    private int veri;  
    private AgacDugumu sol;  
    private AgacDugumu sag;  
  
    public AgacDugumu(int veri) {  
        this.veri = veri;  
        this.sol = null;  
        this.sag = null;  
    }  
}
```

# İkili Arama Ağacına Öge Eklenmesi





metot çağırımı

satır no

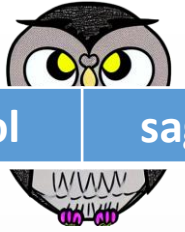
kok

sonuc

sol

sag

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
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metot çağırımı

satır no

kok

sonuc

sol

sag

kok → null

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11    return kok;
12 }
```



kok → null

metot çağırımı	satır no	kok	sol	sag	deger
→ ekle		null	null	null	5

deger = 5

```
→ 1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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5         return kok;
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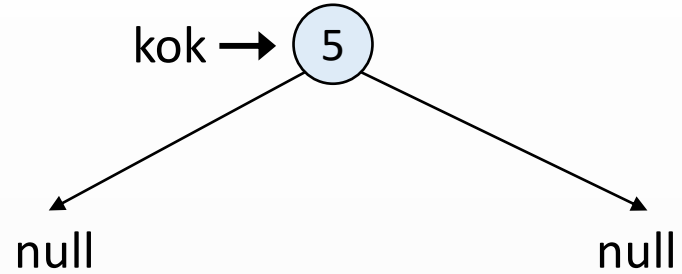


kok → null

metot çağırımı	satır no	kok	sol	sag	deger
ekle		null	null	null	5

deger = 5

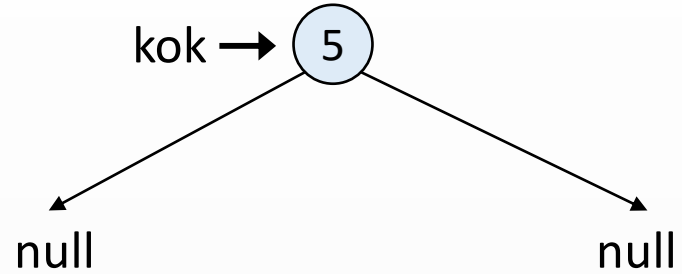
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10        kok.sag = ekle(kok.sag, deger);
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```



metot çağırımı	satır no	kok	sol	sag	deger
→ ekle		5	null	null	5

deger = 5

```
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metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	null	null	5

deger = 5

```
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metot çağırımı

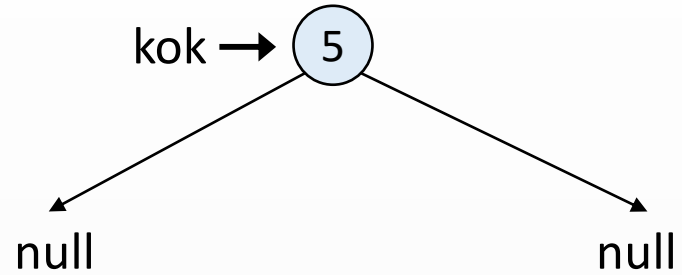
satır no

kok

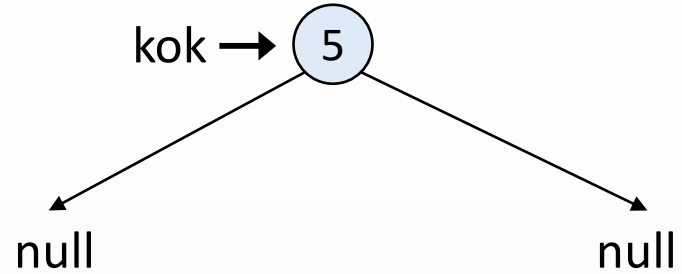
sol

sag

deger



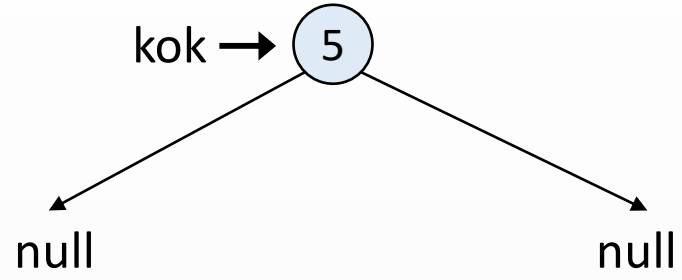
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metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	null	null	3

deger = 3

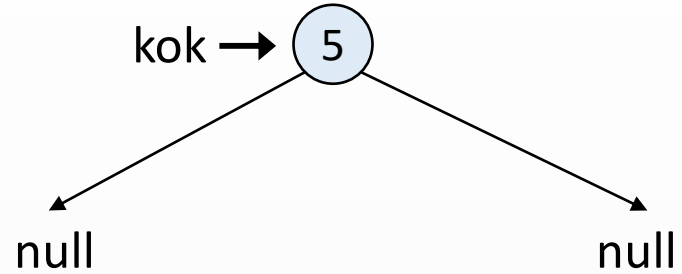
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ekle		5	null	null	3

deger = 3

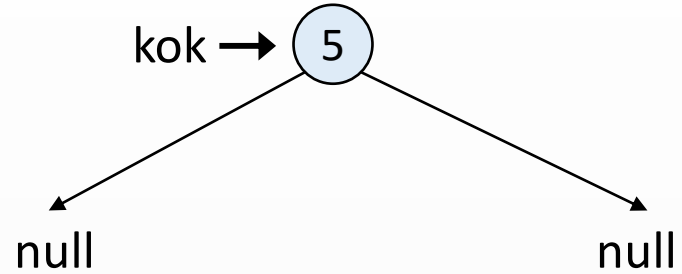
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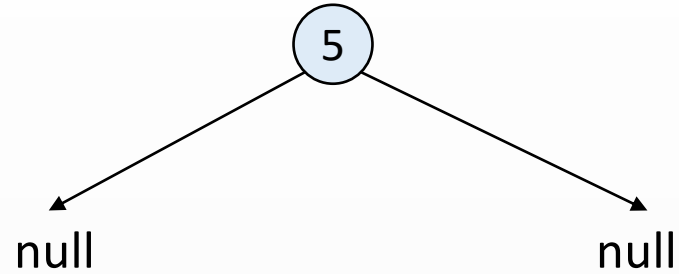
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metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3

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kok → null

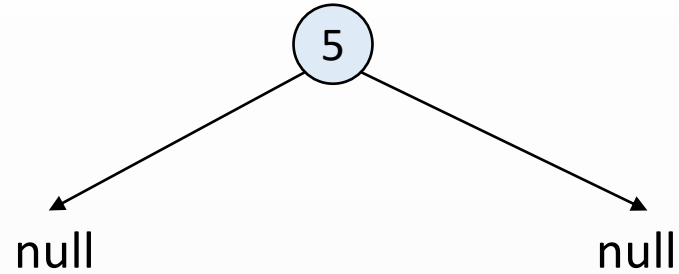
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metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		null	null	null	3



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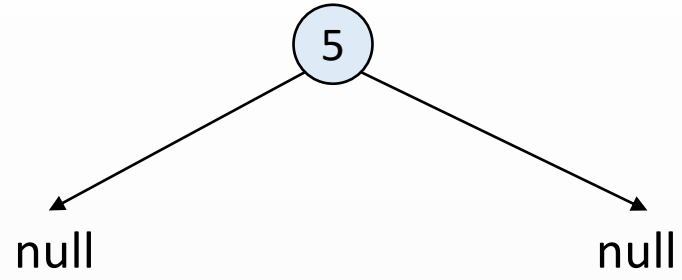
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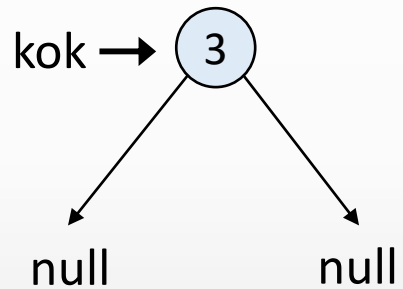
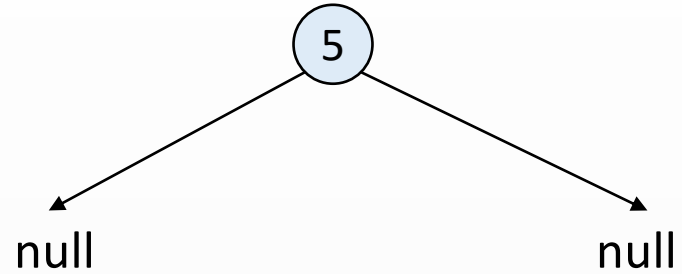


metot çağırımı	satır no	kok	sol	sag	deger
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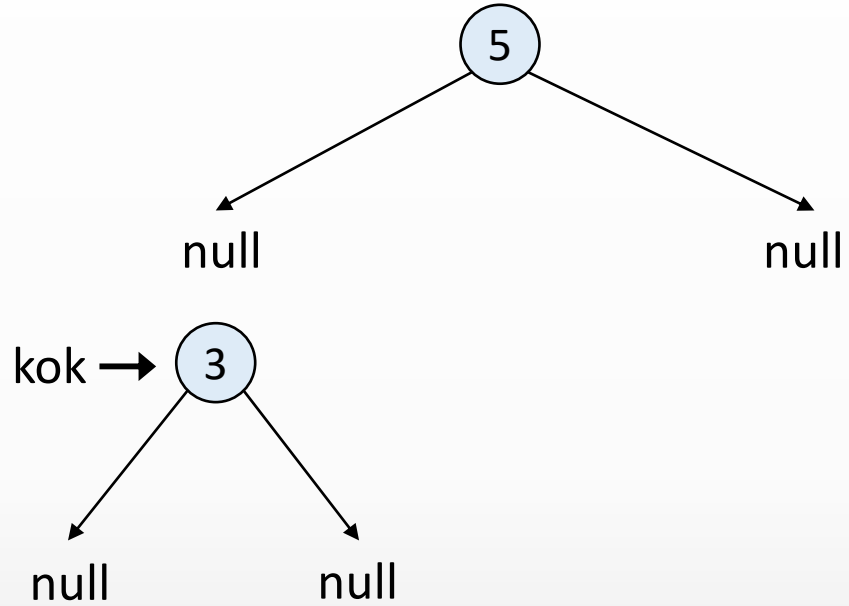
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metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		3	null	null	3



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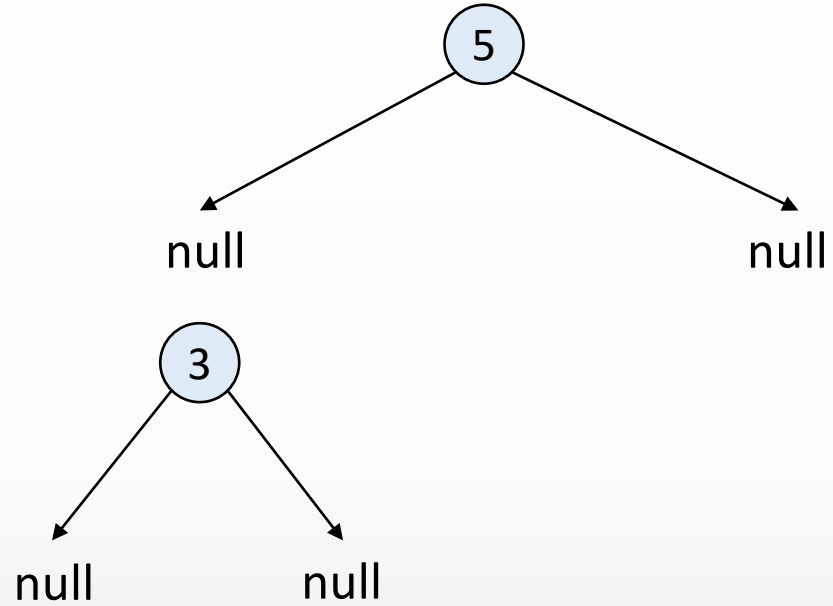
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metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		3	null	null	3

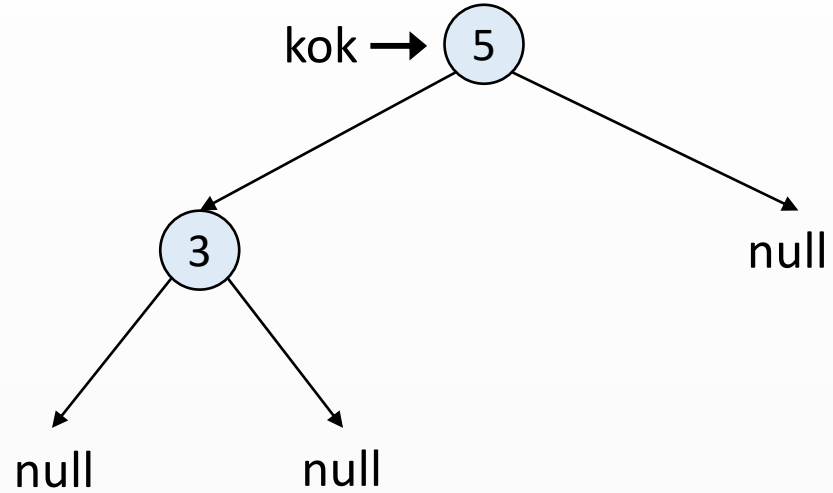


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metot çağırımı	satır no	kok	sol	sag	deger
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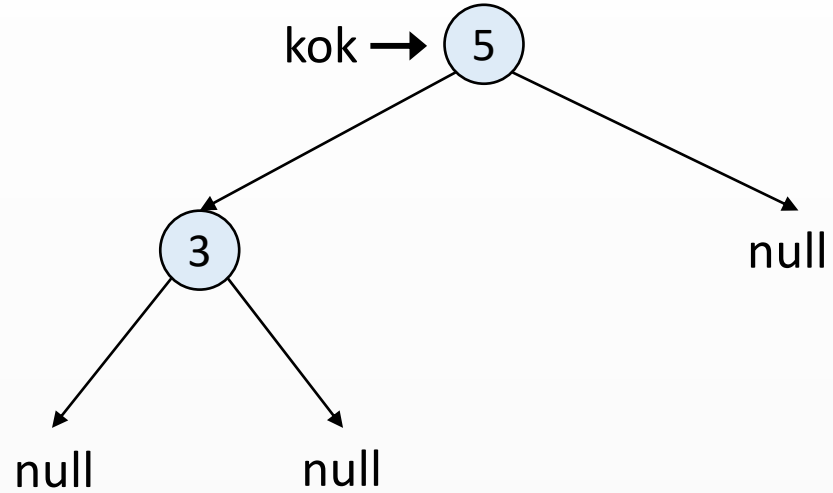
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metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	null	3

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metot çağırımı

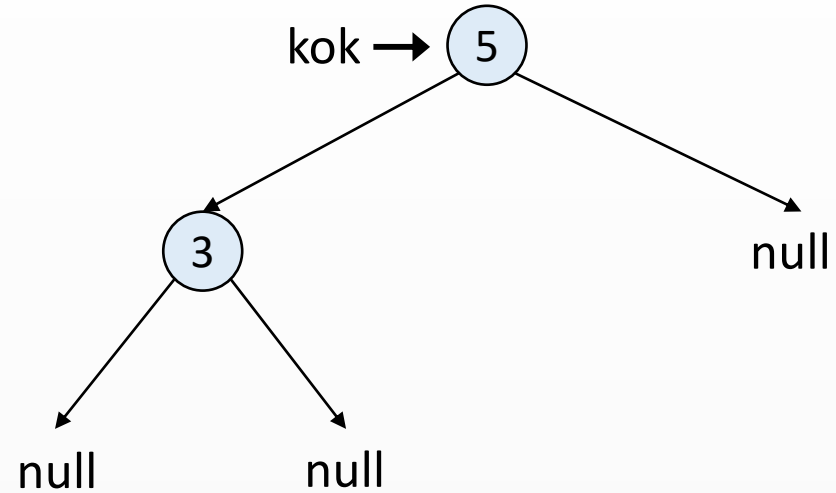
satır no

kok

sol

sag

deger



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metot çağırımı

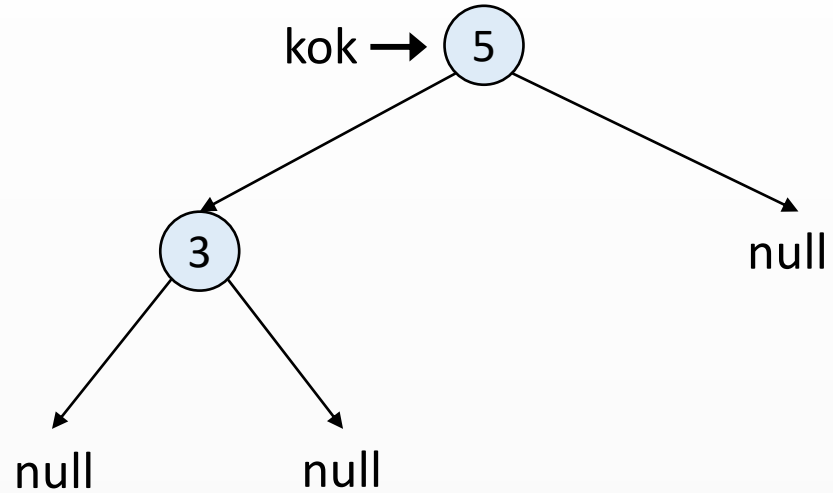
satır no

kok

sol

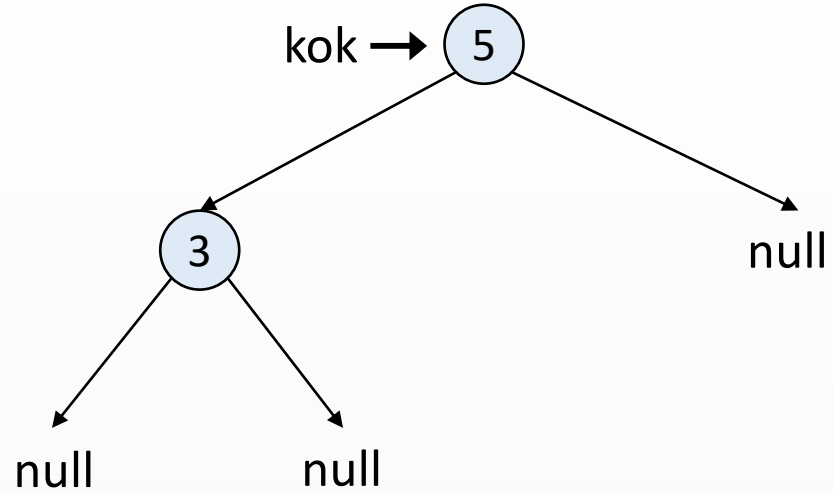
sag

deger



deger = 7

```
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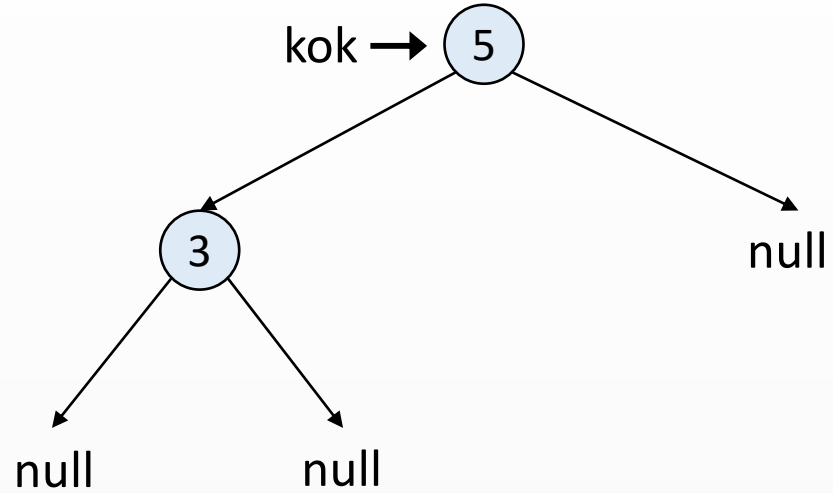


deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

```
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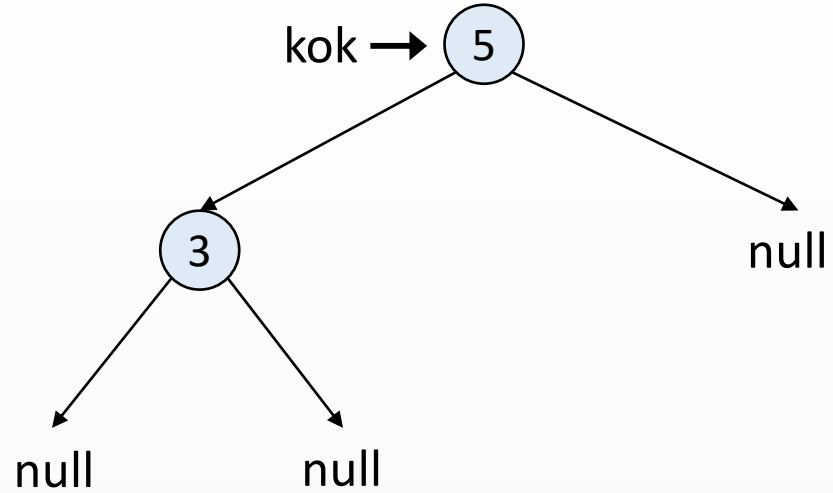




deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

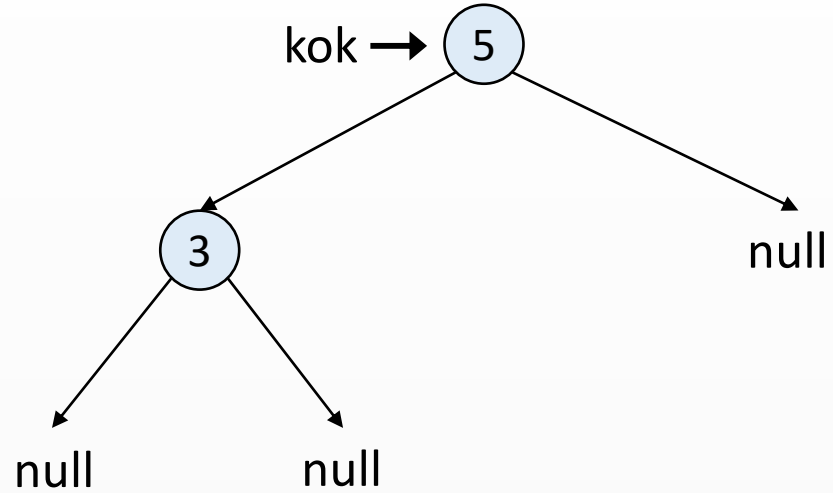
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deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

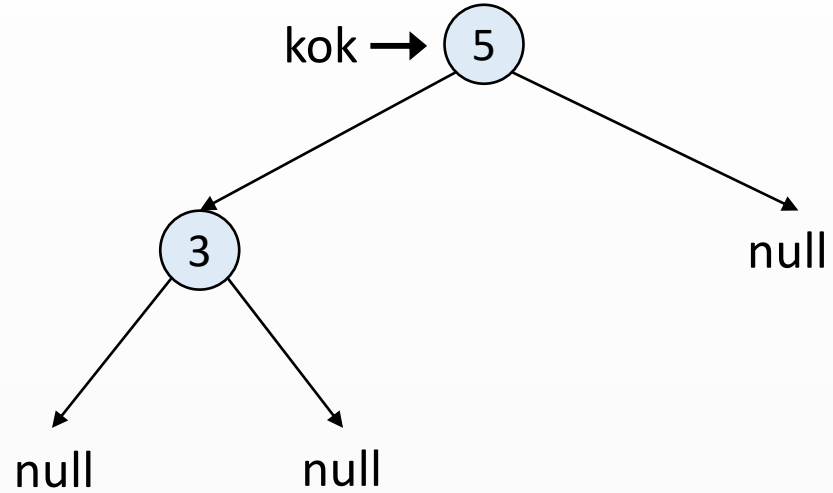
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metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

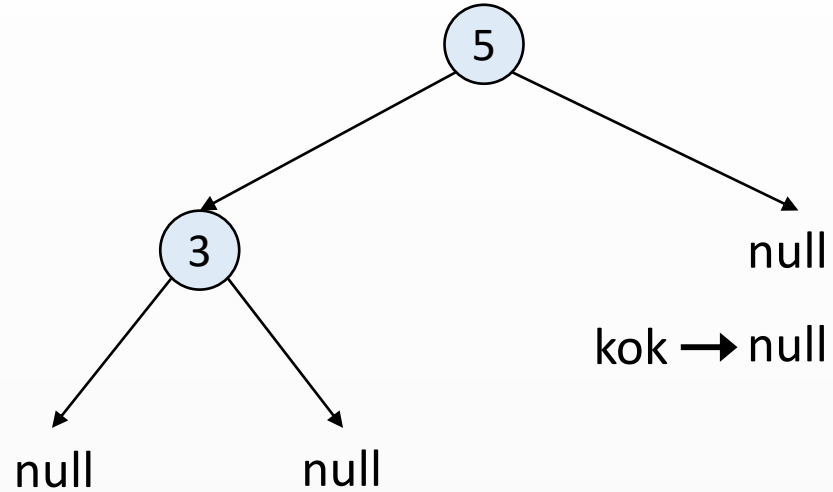
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deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7

```
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3     if(kok == null) {
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5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



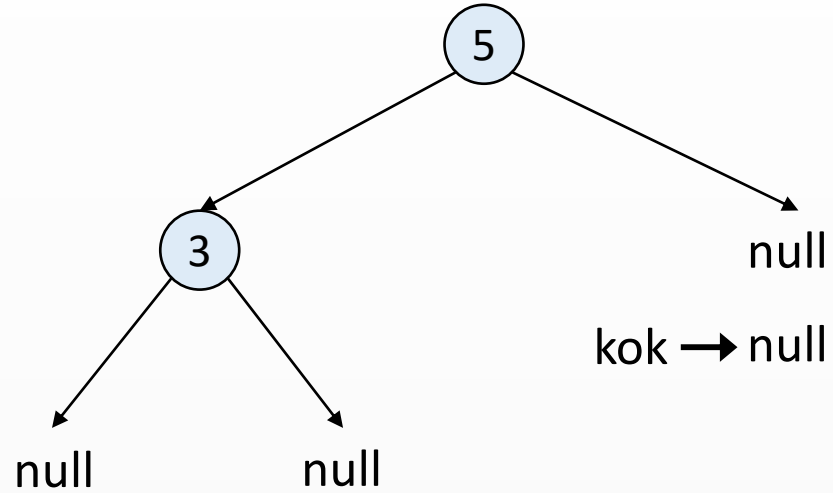
deger = 7



metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		null	null	null	7



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



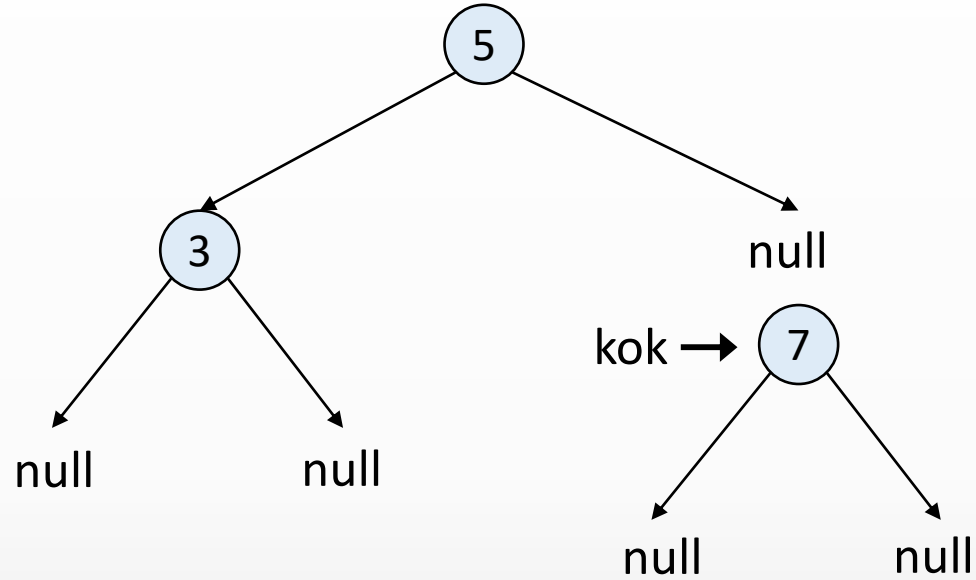
deger = 7



metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		null	null	null	7



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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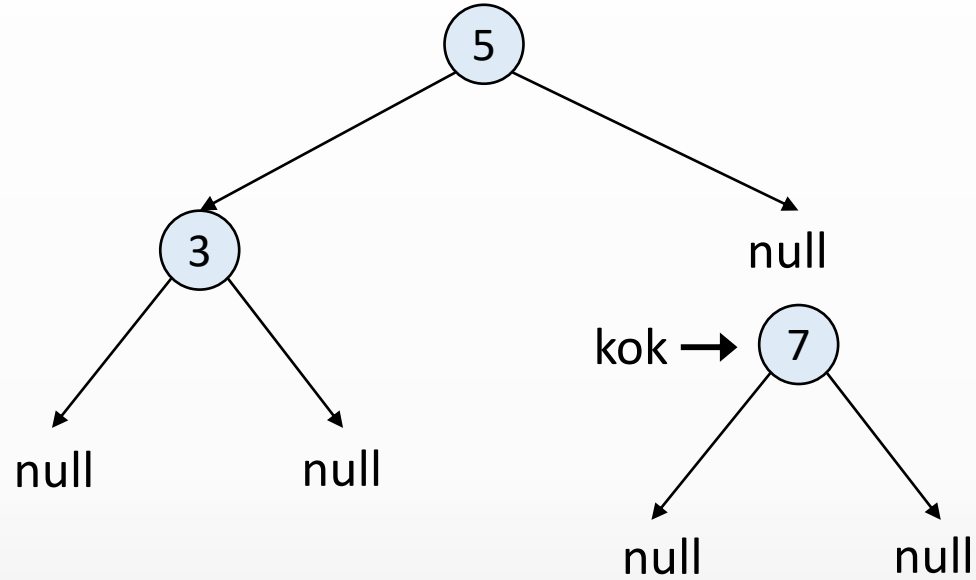
deger = 7



metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		7	null	null	7



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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9     else
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11    return kok;
12 }
```



deger = 7

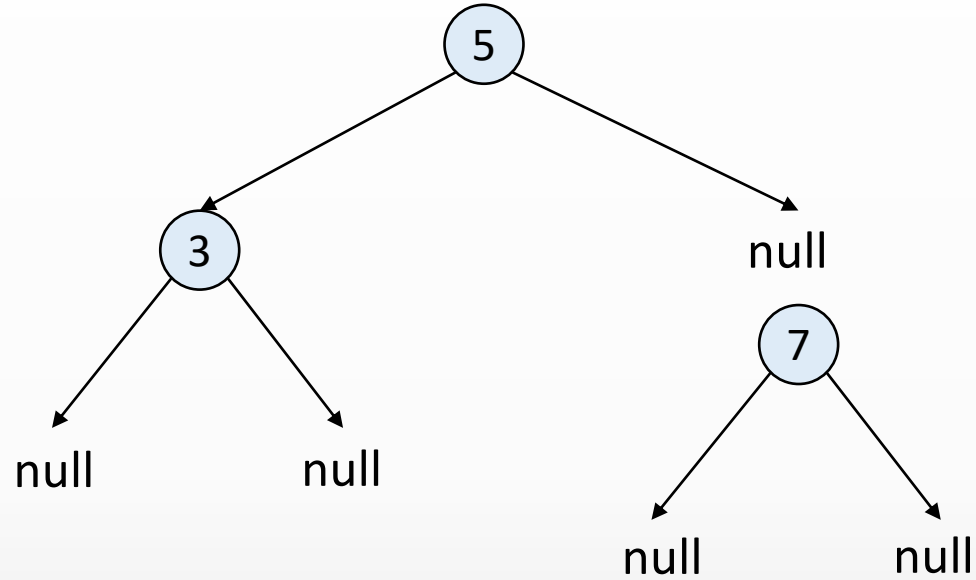


metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		7	null	null	7



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



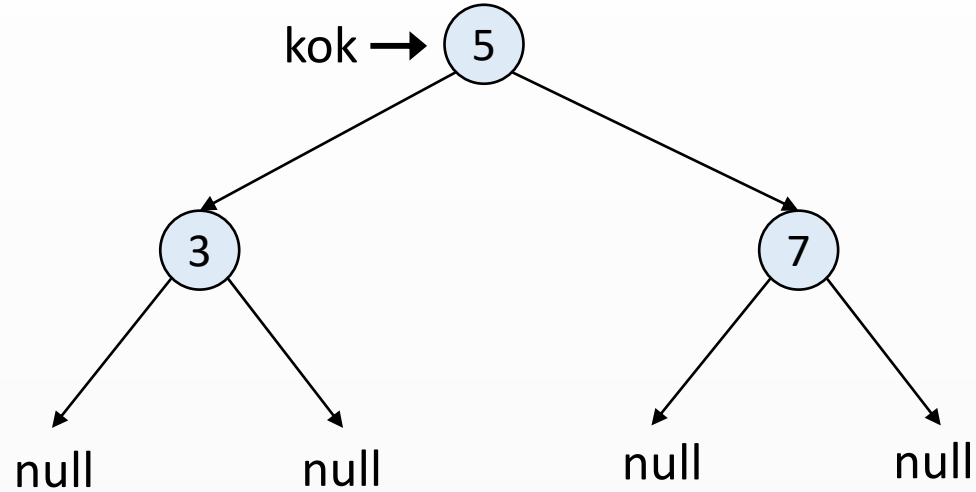


deger = 7



metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7

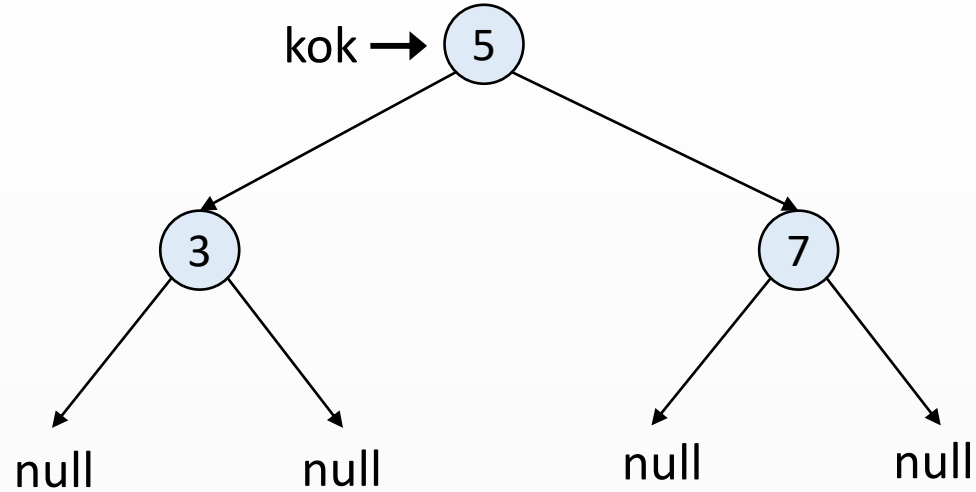
```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
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9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	7	7

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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```



deger = 7

metot çağırımı	satır no	kok	sol	sag	deger
ekle	10	5	3	7	7

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



metot çağırımı

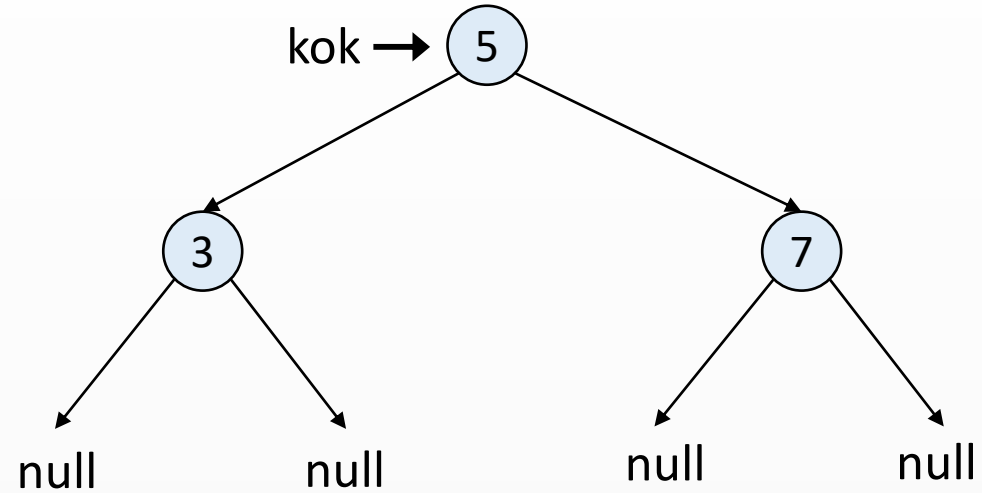
satır no

kok

sol

sag

deger



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
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7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



metot çağırımı

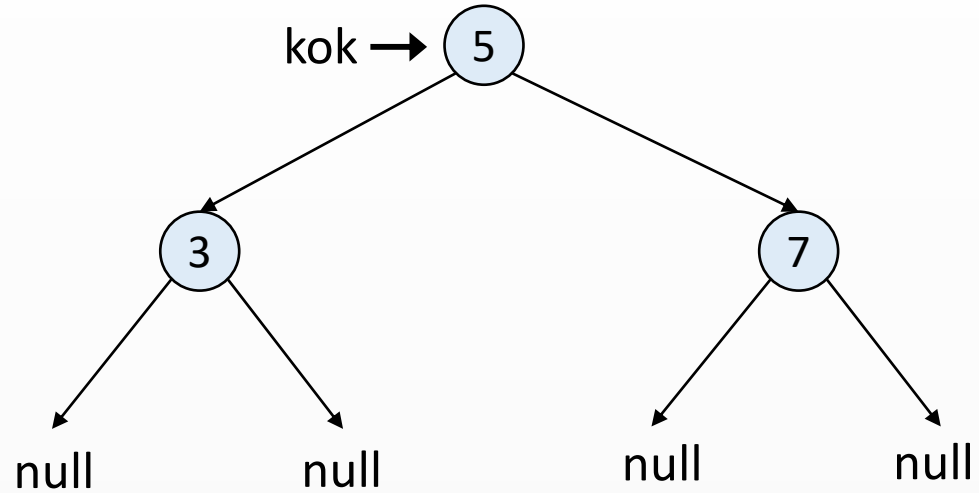
satır no

kok

sol

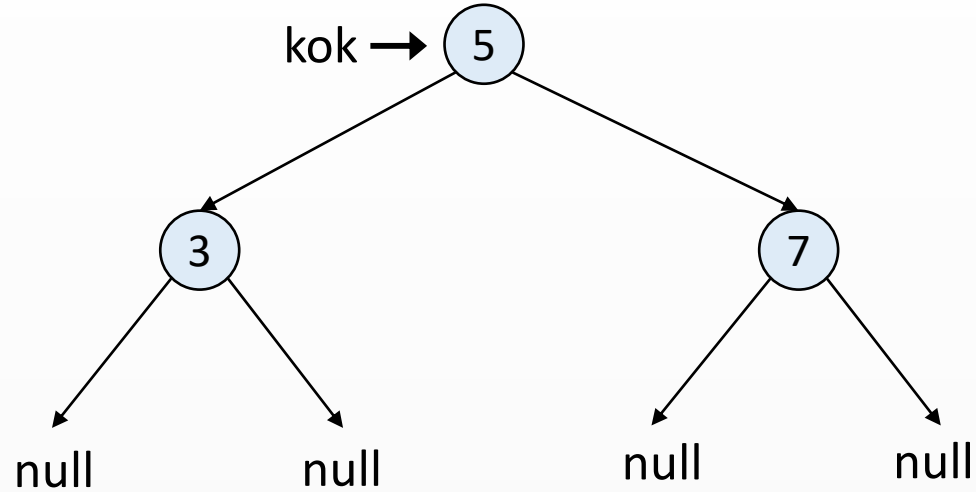
sag

deger



deger = 1

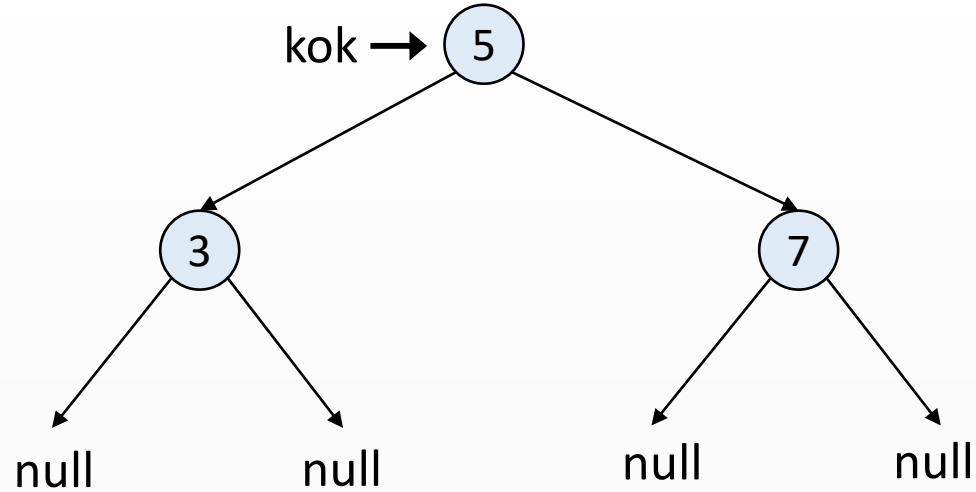
```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



deger = 1

metot çağırımı	satır no	kok	sol	sag	deger
→ ekle		5	3	7	1

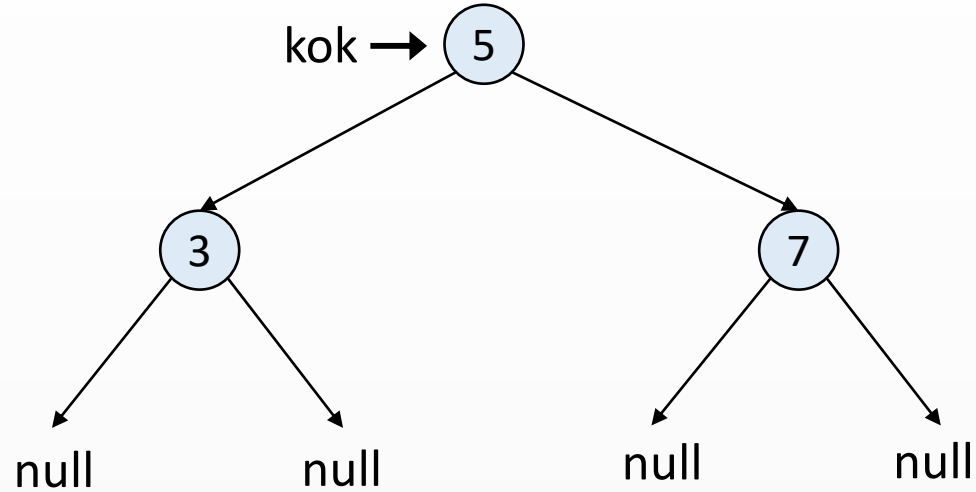
```
→ 1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



deger = 1

metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	7	1

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```

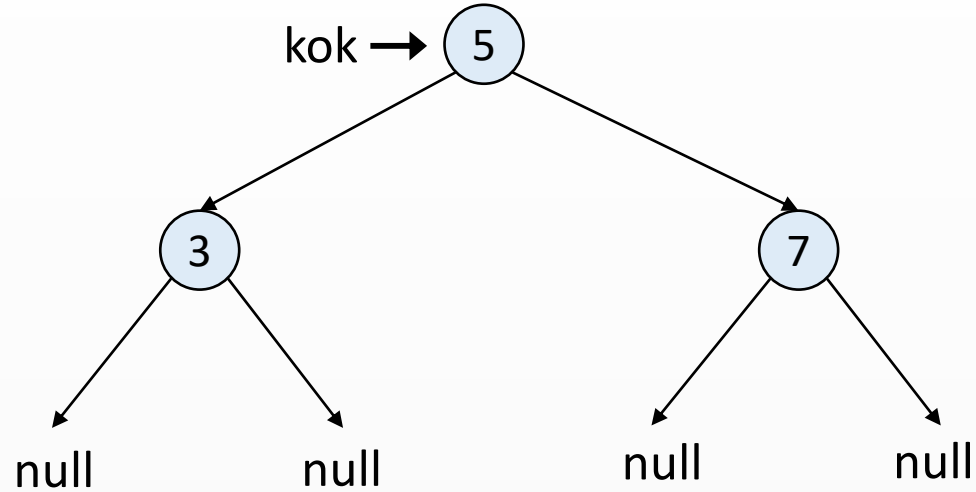


deger = 1

metot çağırımı	satır no	kok	sol	sag	deger
ekle		5	3	7	1

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```





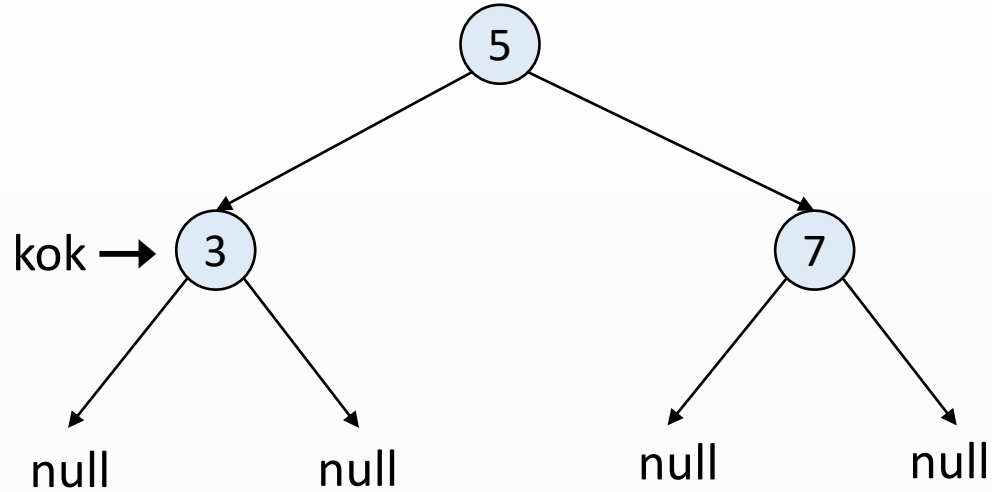
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



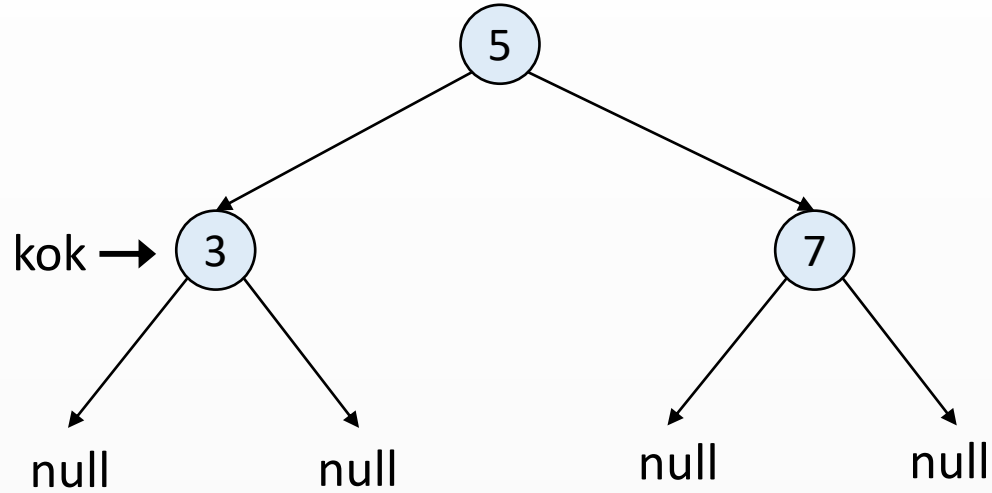
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
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7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



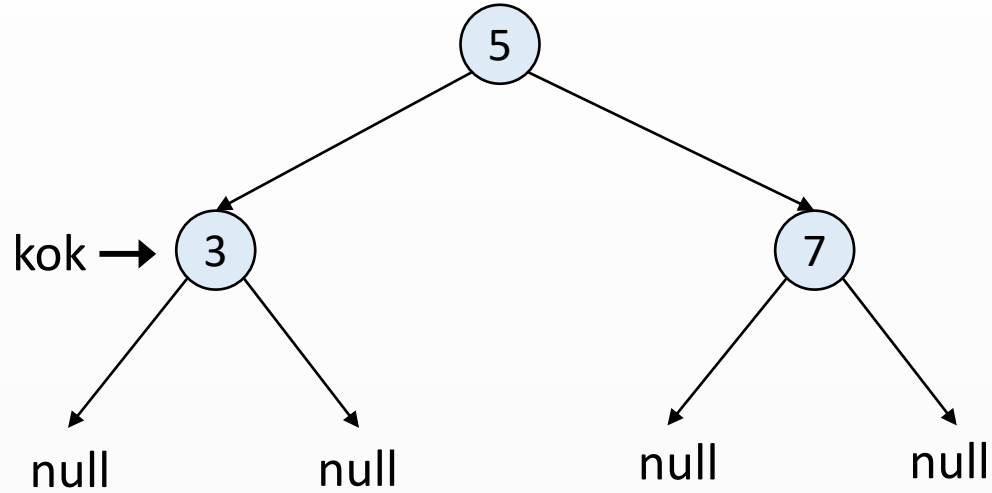
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
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11    return kok;
12 }
```



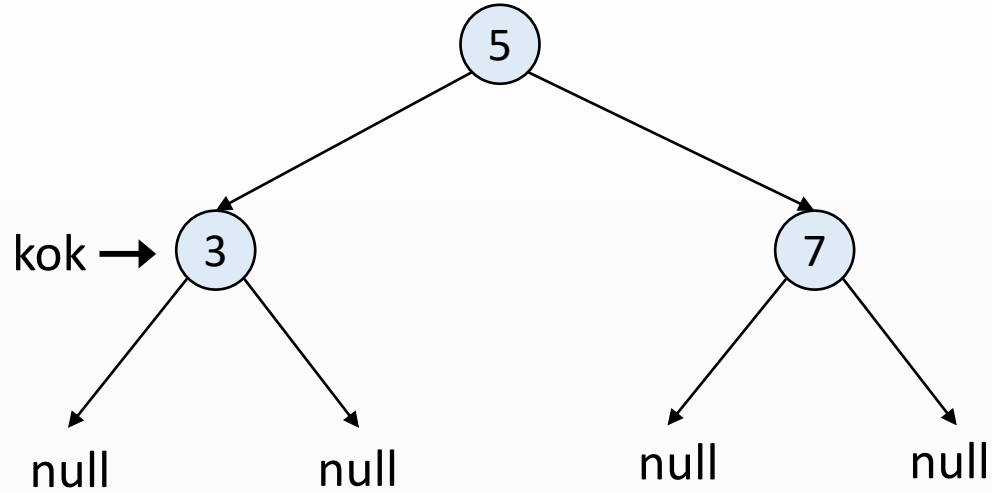
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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5         return kok;
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7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



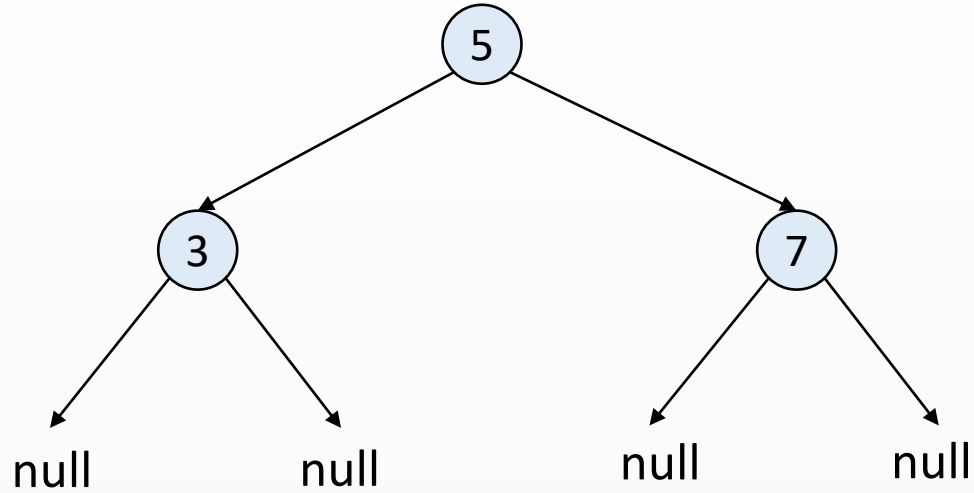
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



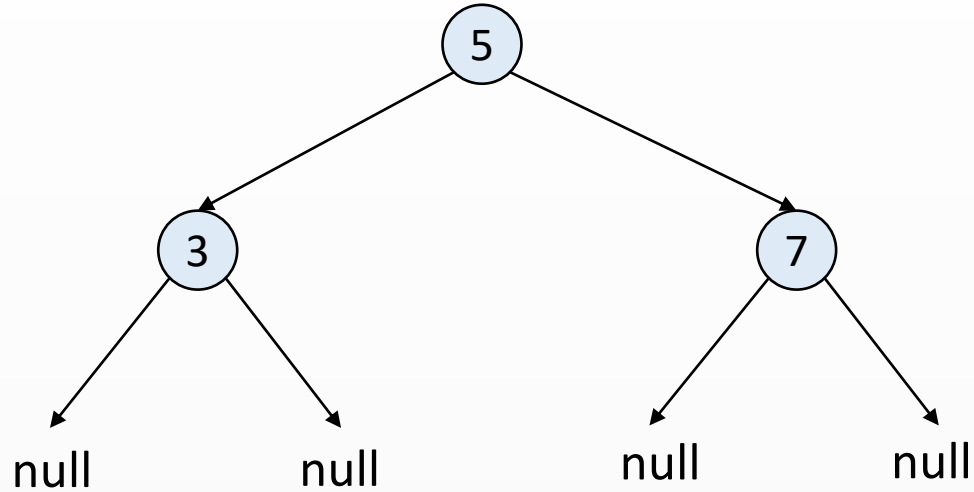
metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1
ekle		null	null	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
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6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```

kok → null

deger = 1



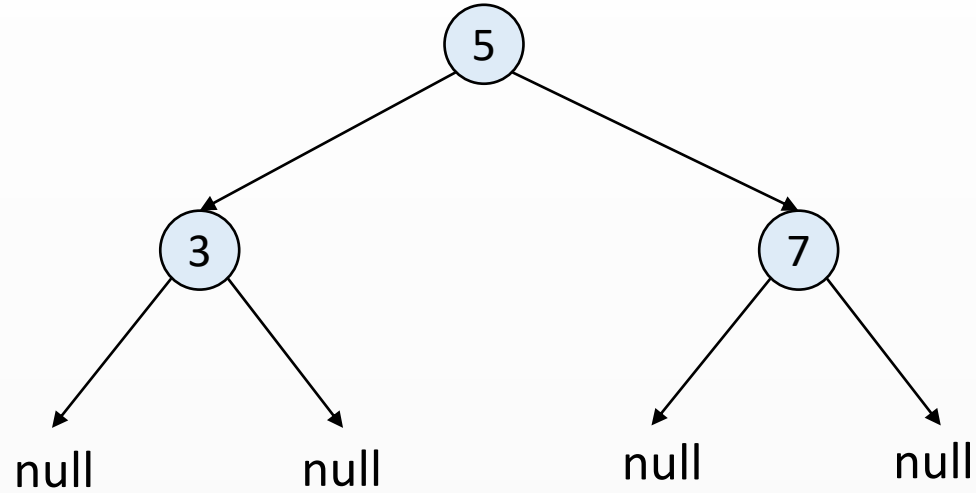
metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1
ekle		null	null	null	1



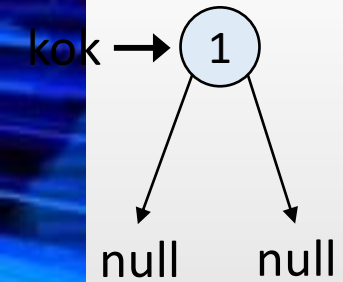
```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```

kok → null

deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1
ekle		null	null	null	1

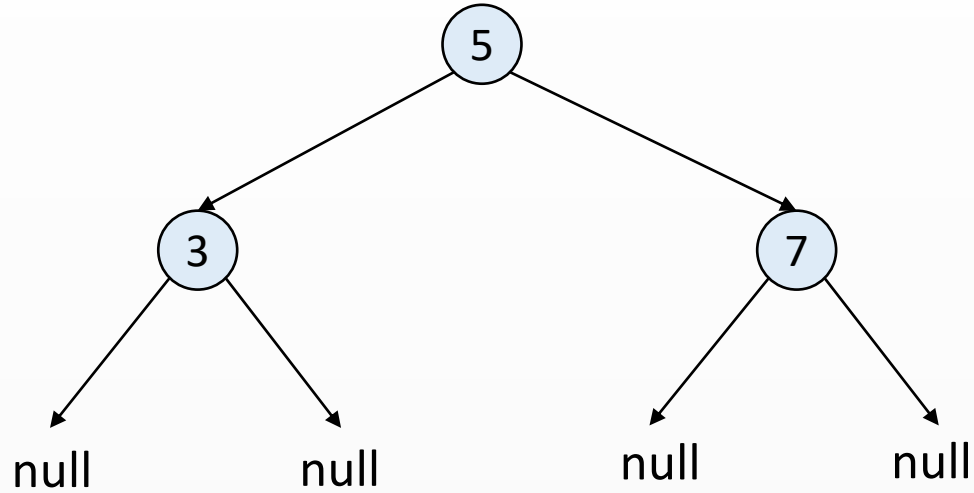


deger = 1

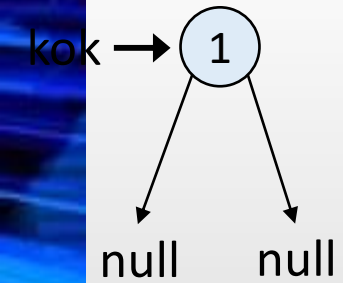


```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
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5         return kok;
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9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
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```





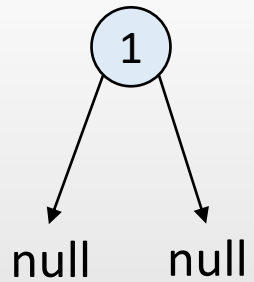
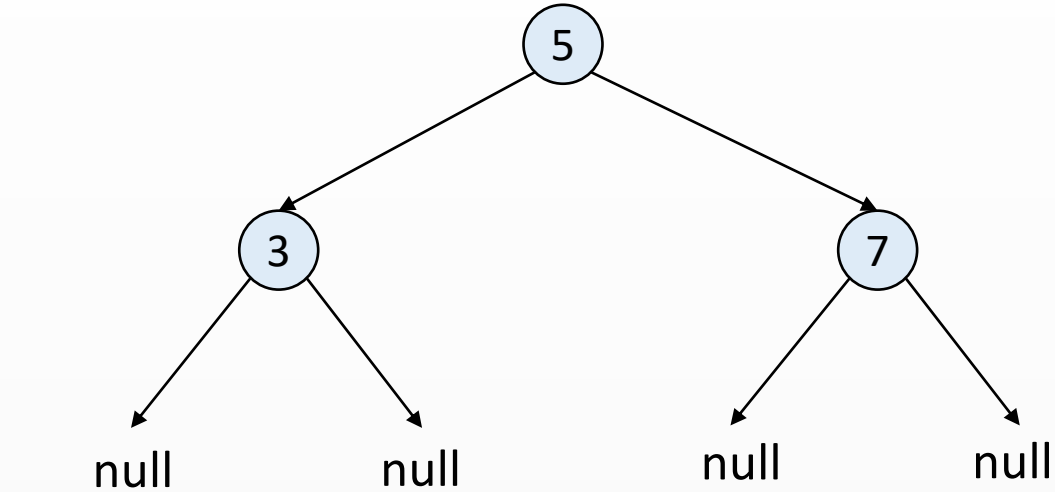
metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1
ekle		null	null	null	1



deger = 1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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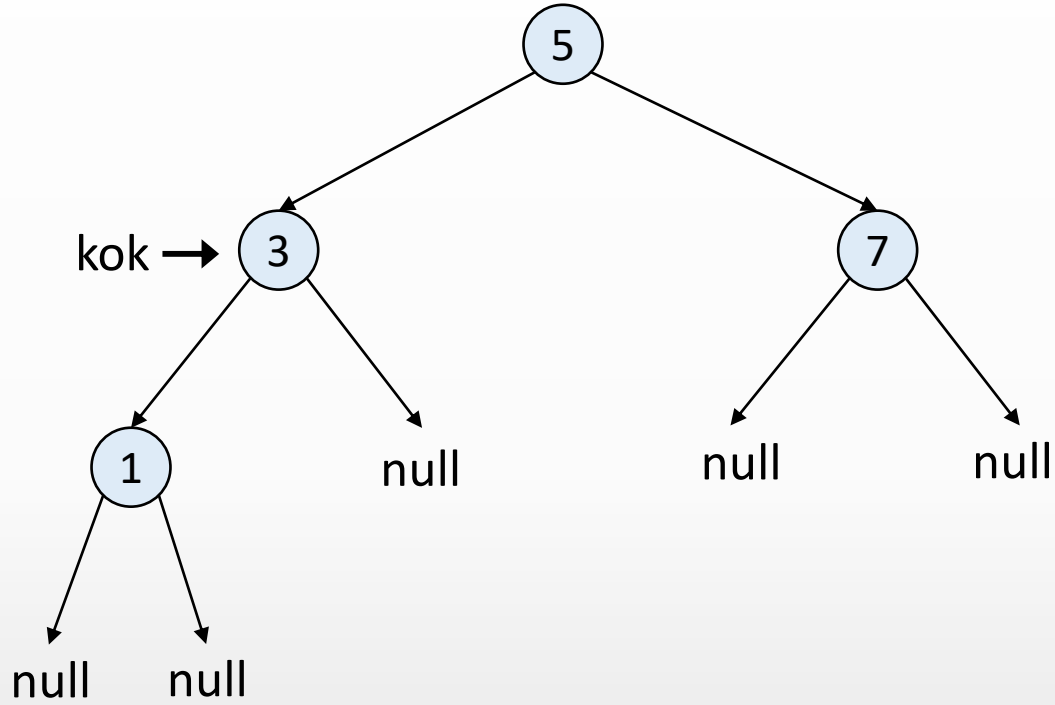


deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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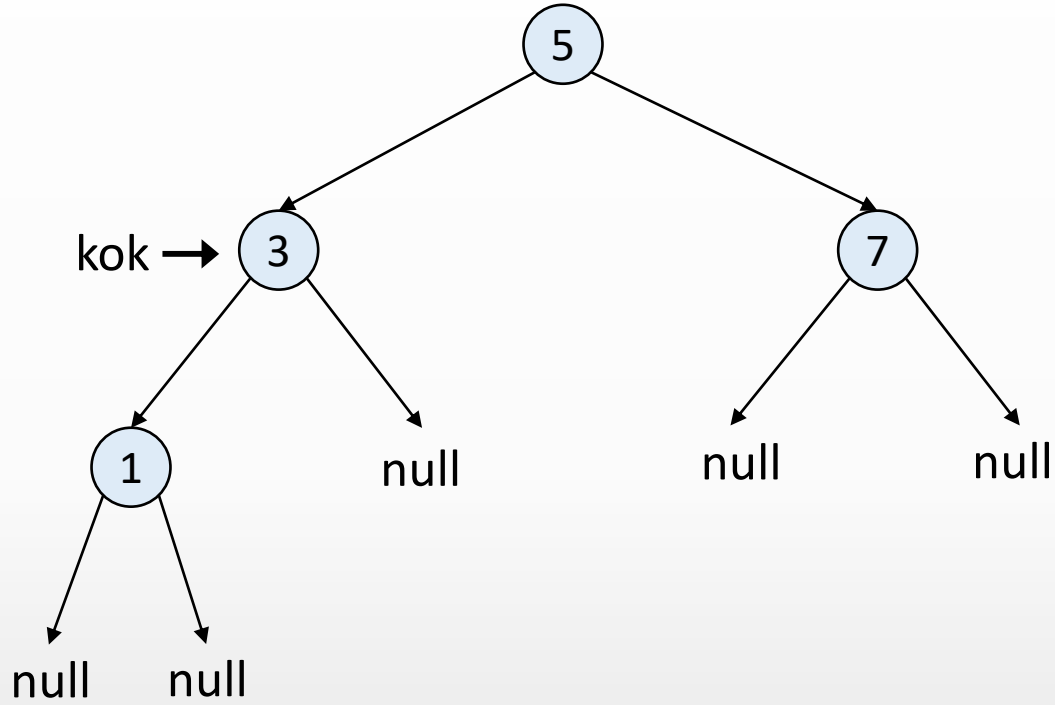
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	1	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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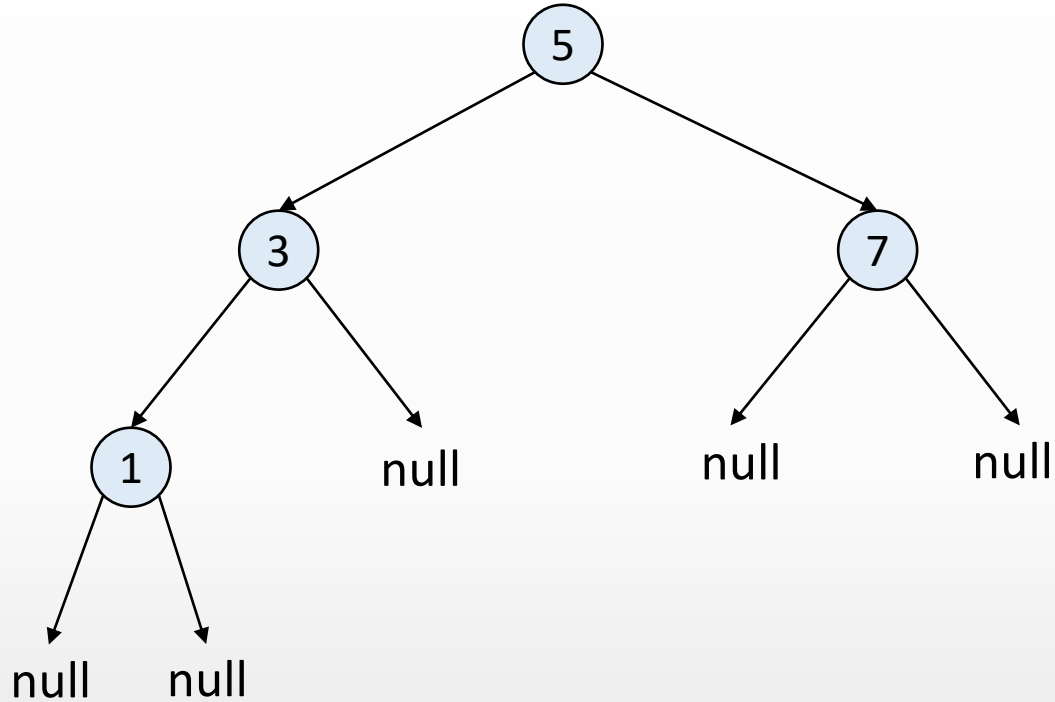
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	1	null	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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9     else
10        kok.sag = ekle(kok.sag, deger);
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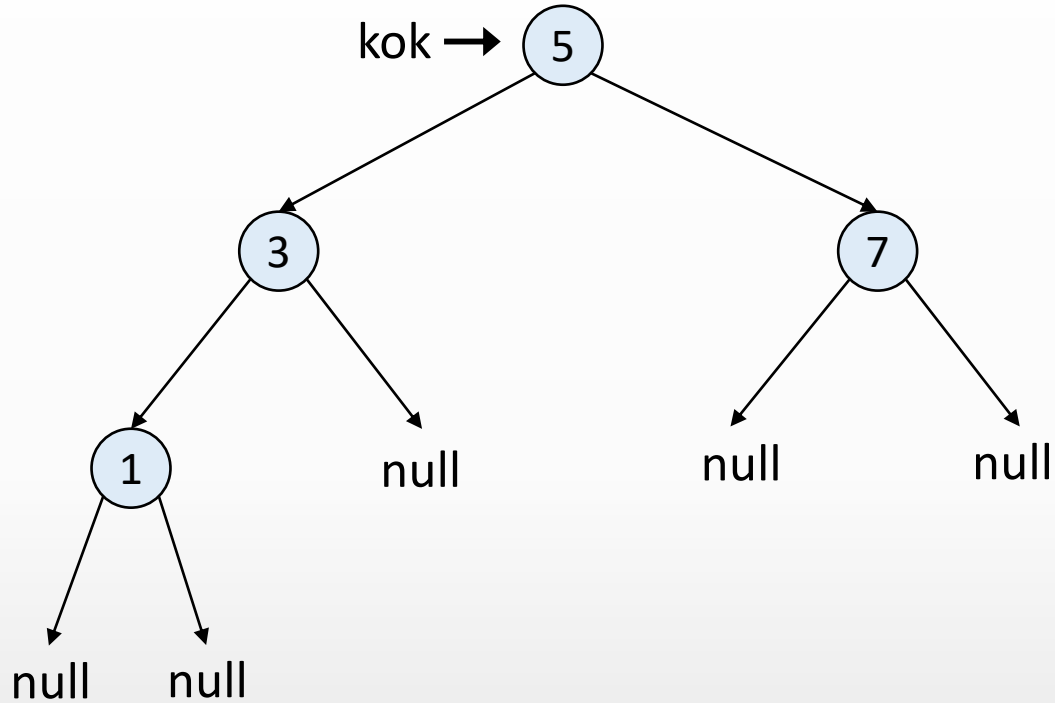


deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
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11    return kok;
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```



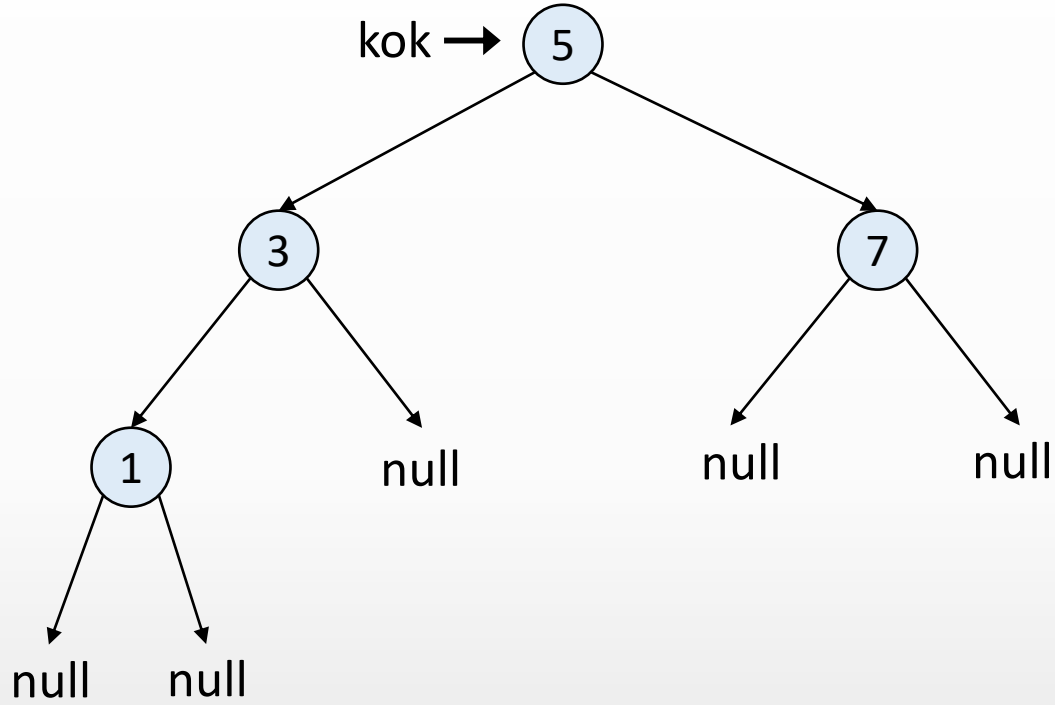
deger = 1



metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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deger = 1

metot çağırımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1

```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
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8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```



metot çağırımı

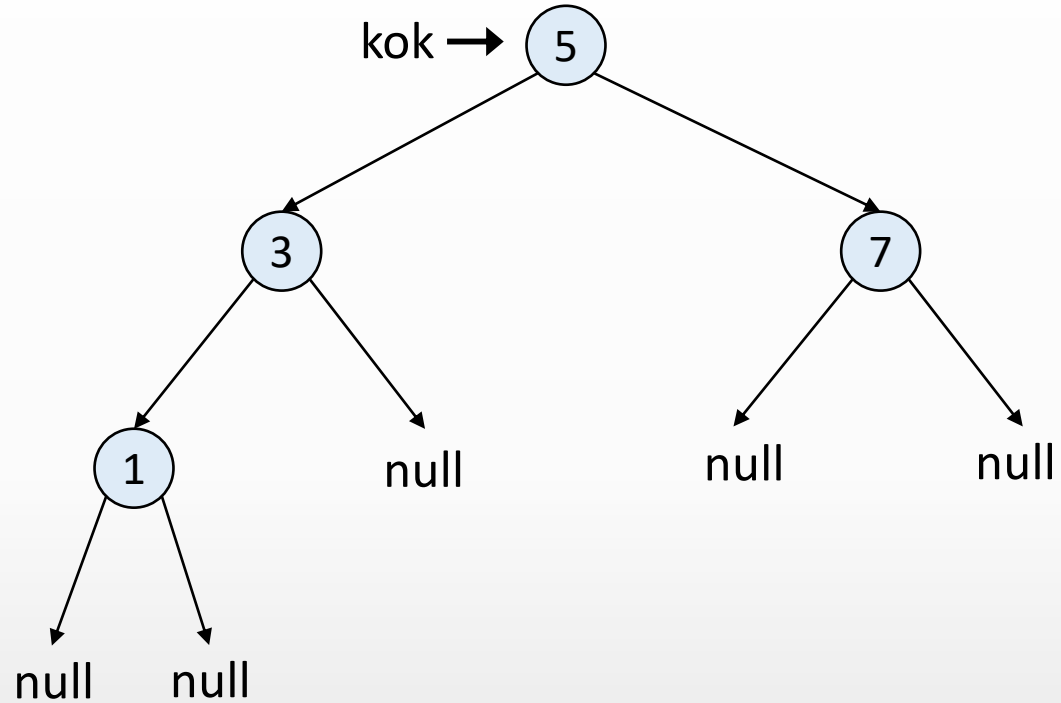
satır no

kok

sol

sag

deger



```
1 public AgacDugumu ekle(AgacDugumu kok, int deger)
2 {
3     if(kok == null) {
4         kok = new AgacDugumu(deger);
5         return kok;
6     }
7     if(deger < kok.veri)
8         kok.sol = ekle(kok.sol, deger);
9     else
10        kok.sag = ekle(kok.sag, deger);
11    return kok;
12 }
```





# Verilen Bir Anahtarı İkili Arama Ağacında Arama

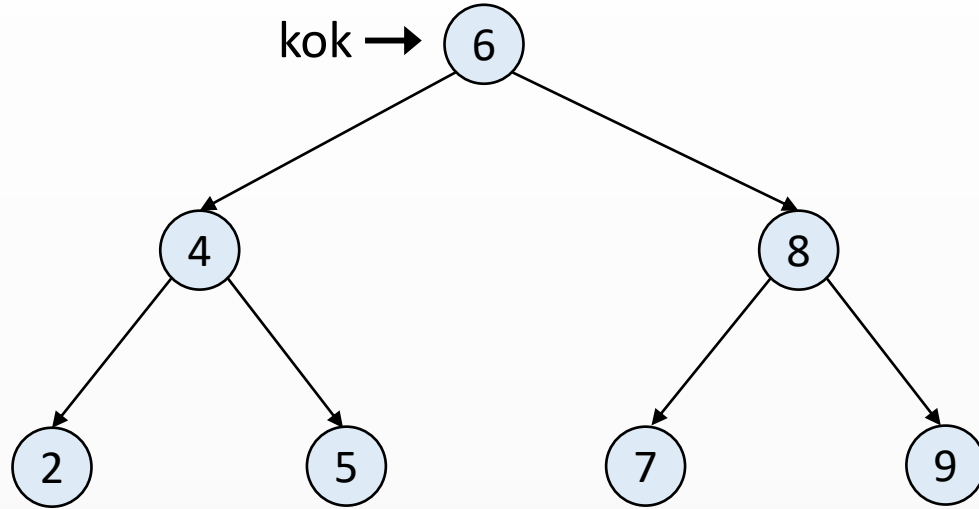


metot çağırımı

satır no

kok

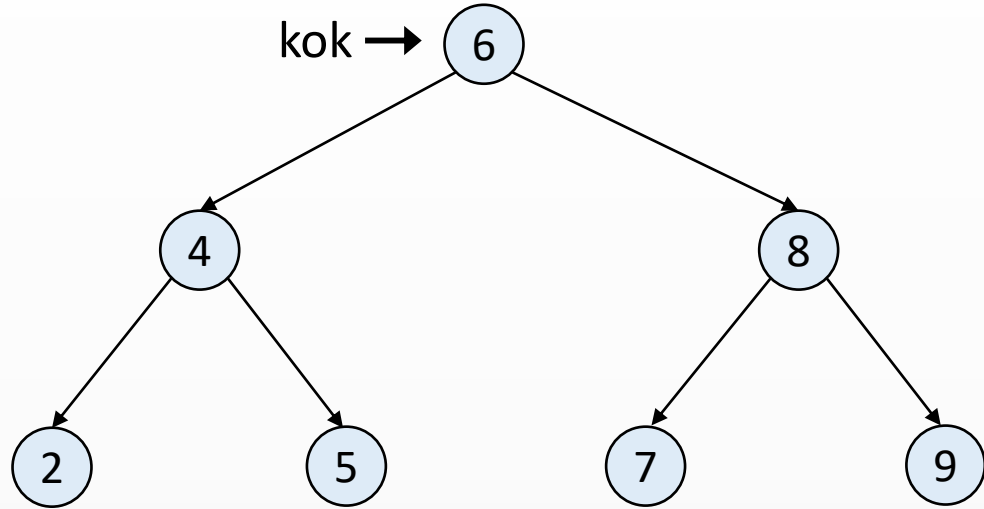
anahtar



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```

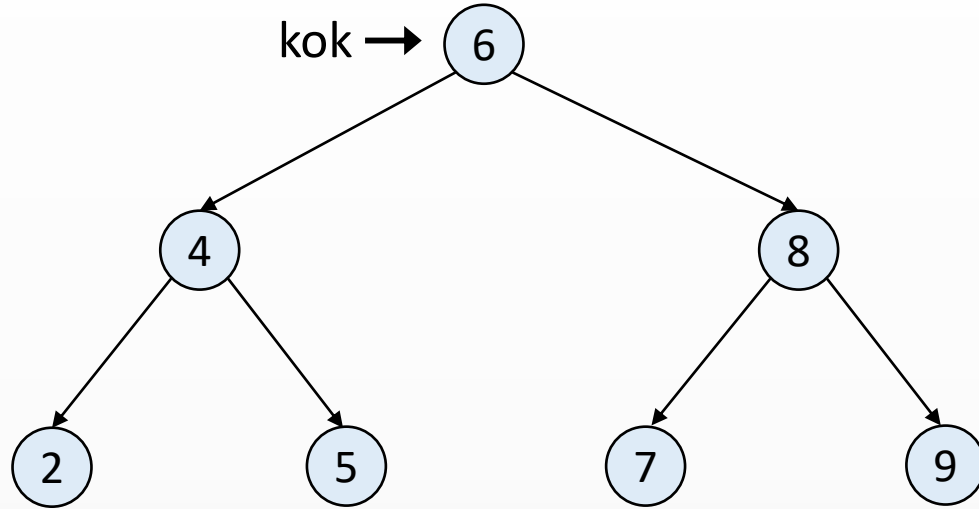


metot çağırımı	satır no	kok	anahtar
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anahtar = 5

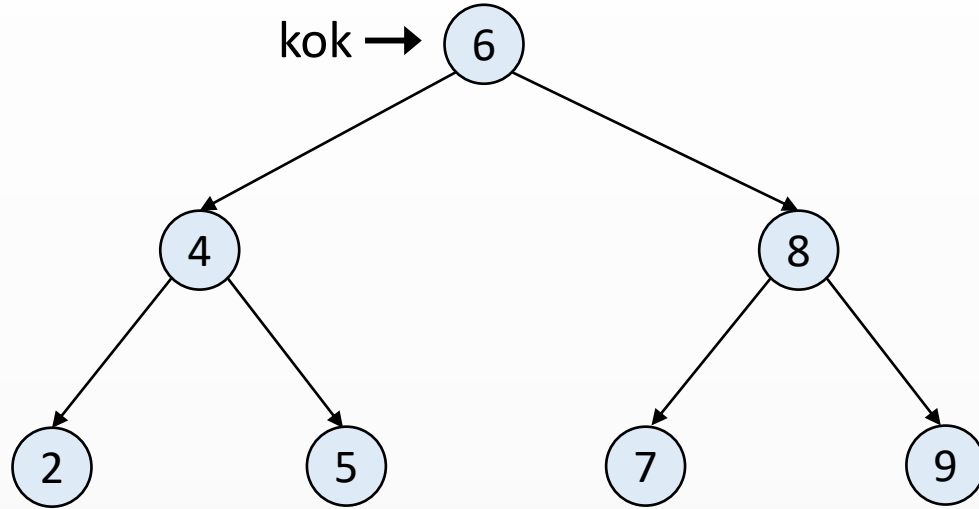
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1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
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7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```



anahtar = 5

metot çağırımı	satır no	kok	anahtar
ara		6	5

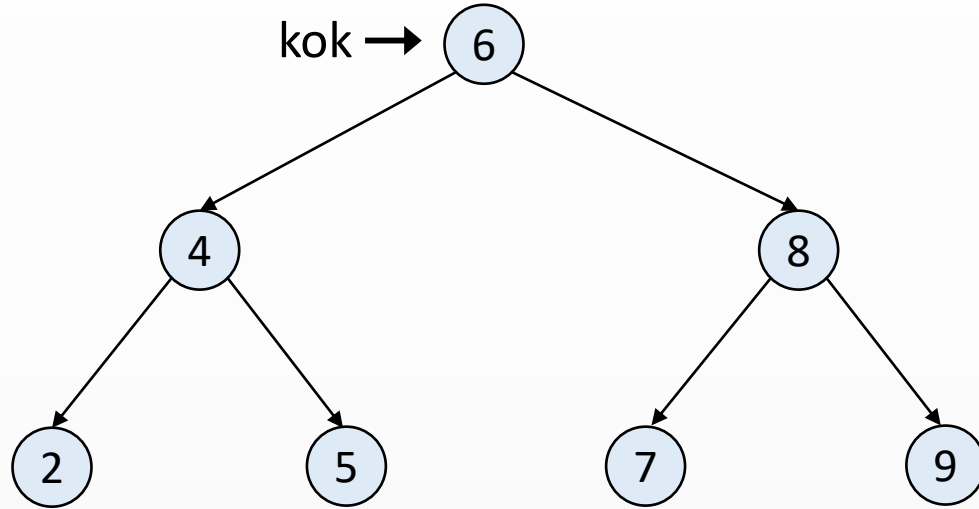
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1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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10 }
```



anahtar = 5

metot çağırımı	satır no	kok	anahtar
ara		6	5

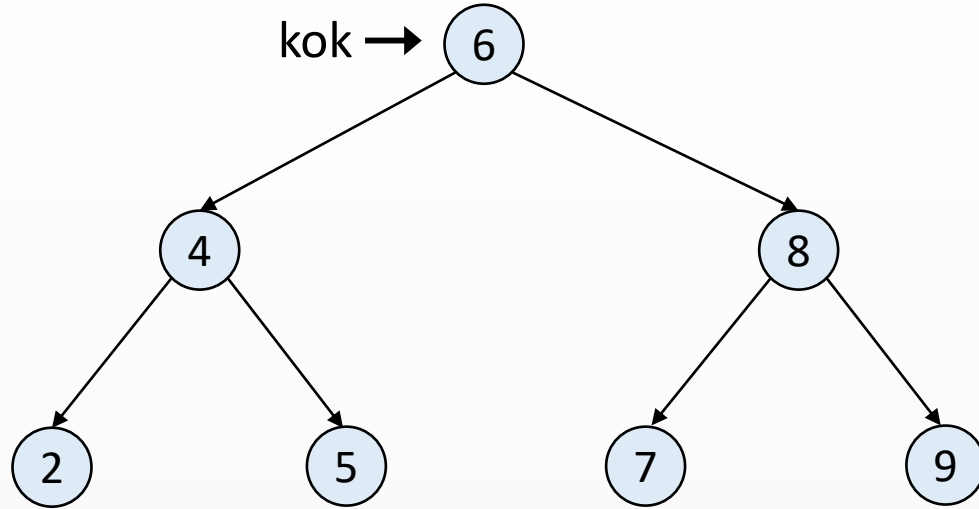
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1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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10 }
```



anahtar = 5

metot çağırımı	satır no	kok	anahtar
ara		6	5

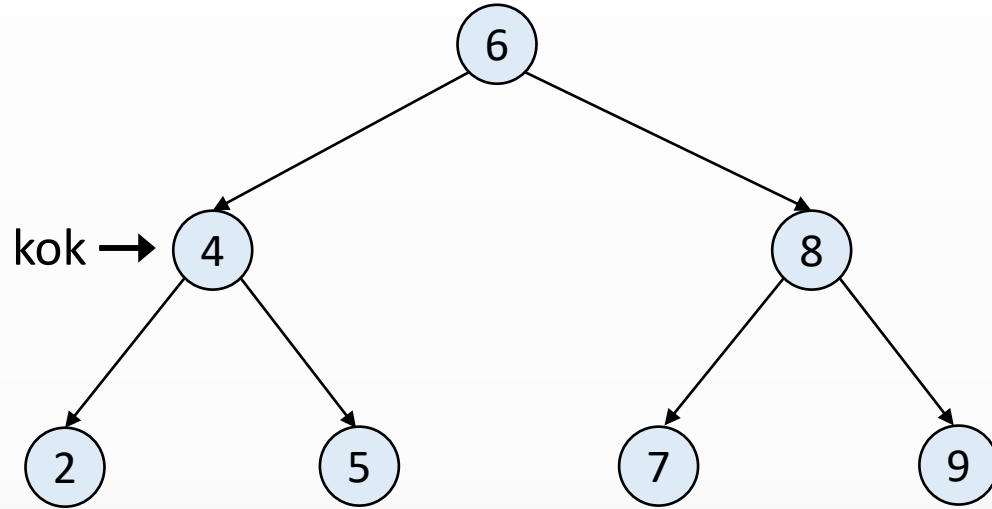
```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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3     if(kok == null || kok.veri == anahtar) {
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5     }
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7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```



anahtar = 5

metot çağırımı	satır no	kok	anahtar
ara	7	6	5

```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```



anahtar = 5

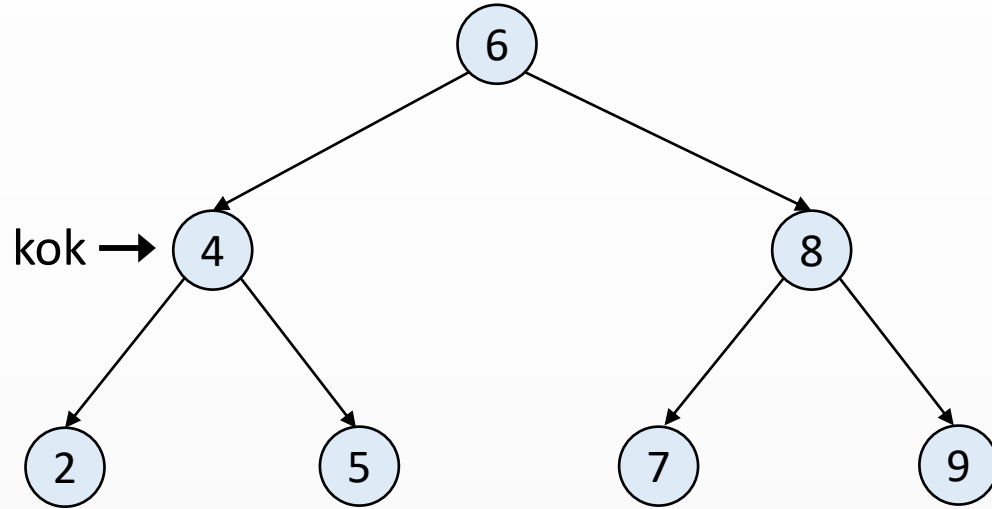


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
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7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```



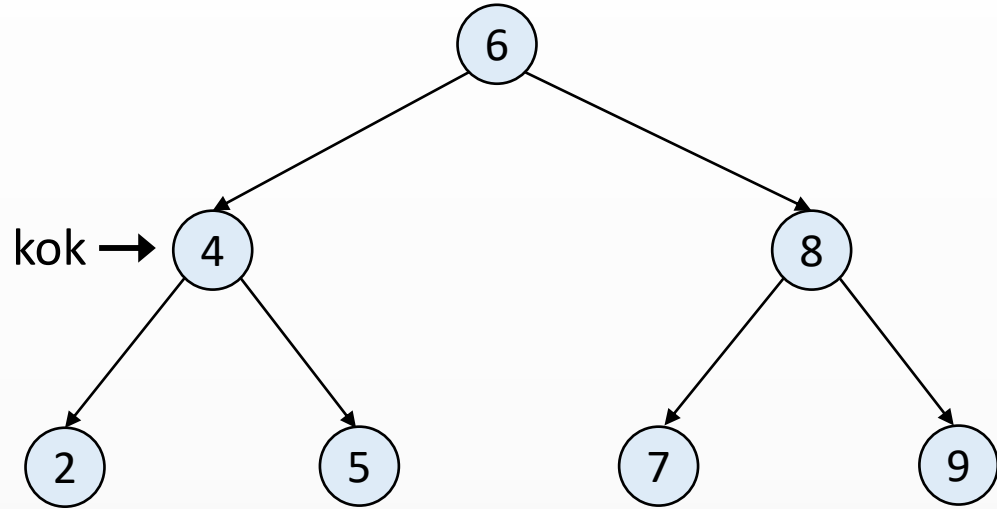


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

anahtar = 5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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7         return ara(kok.sol, anahtar);
8     else
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10 }
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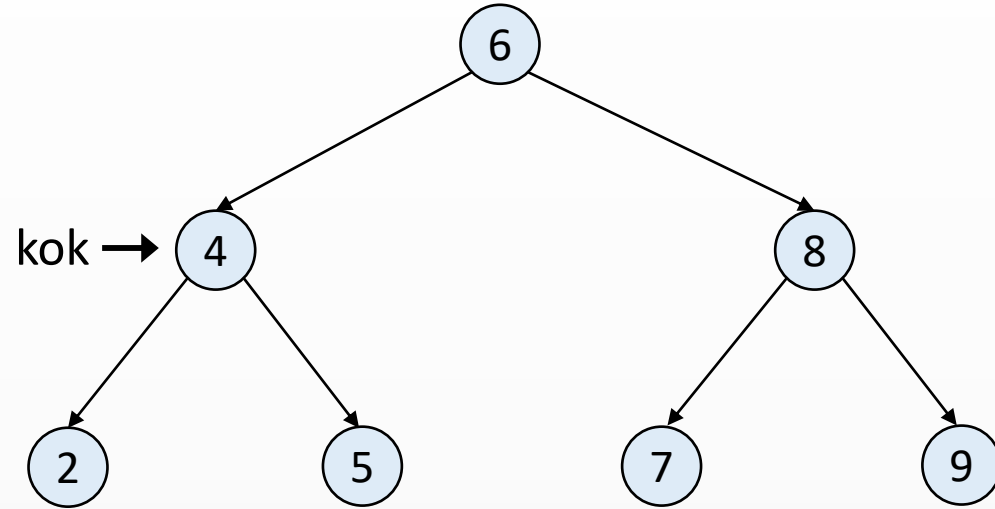


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

anahtar = 5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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10 }
```

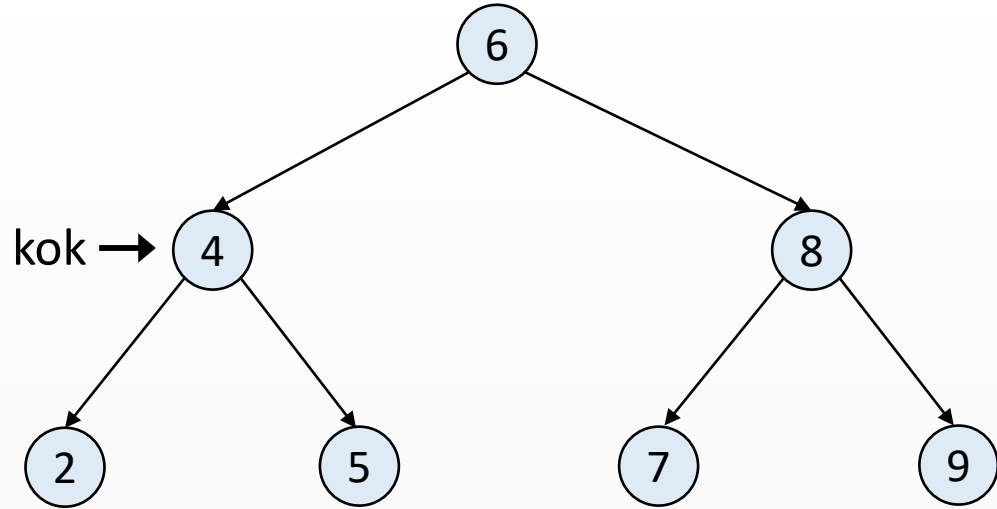


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

anahtar = 5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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10 }
```



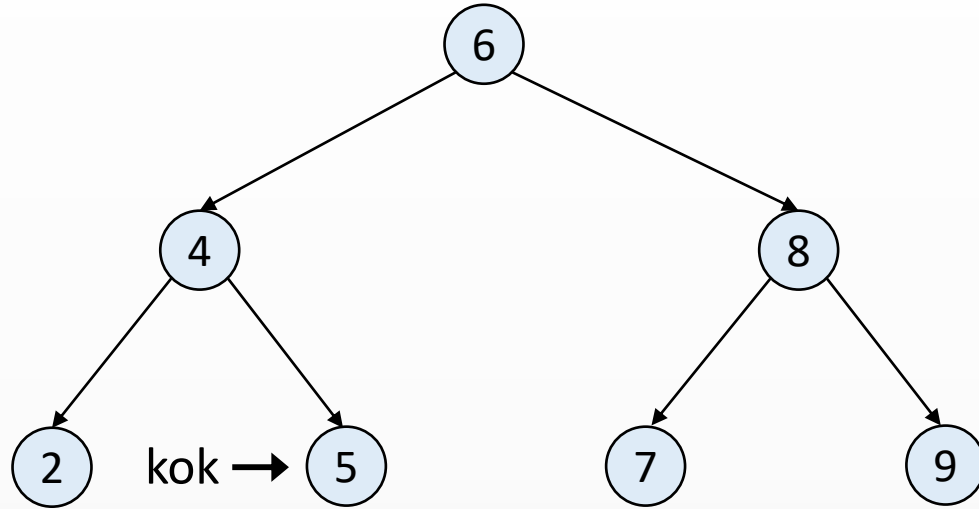
anahtar = 5



metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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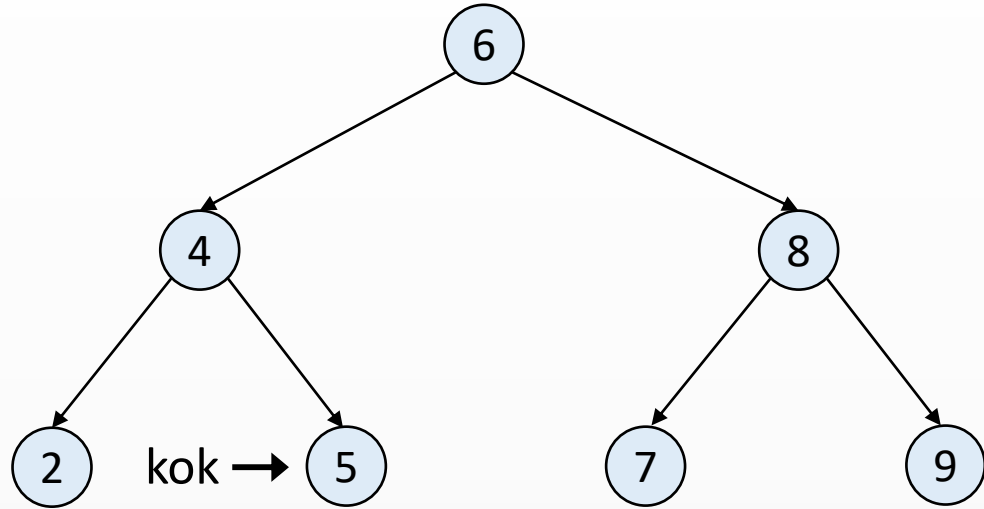
anahtar = 5



metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5
ara		5	5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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```

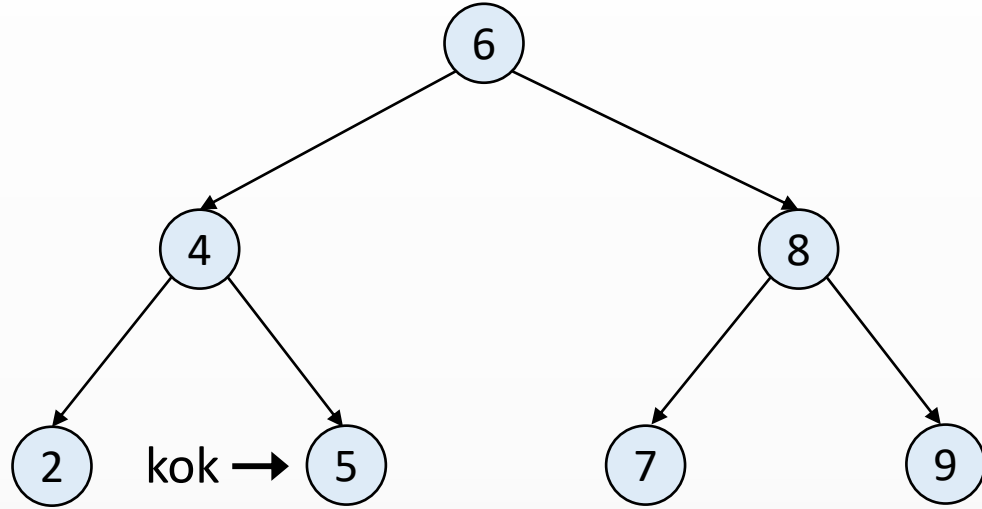


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5
ara		5	5

anahtar = 5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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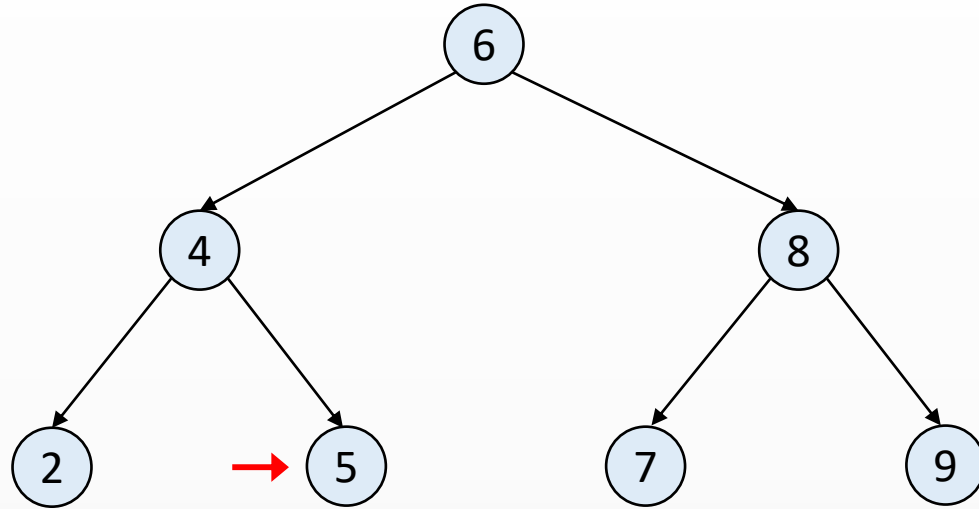
anahtar = 5



metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5
ara		5	5



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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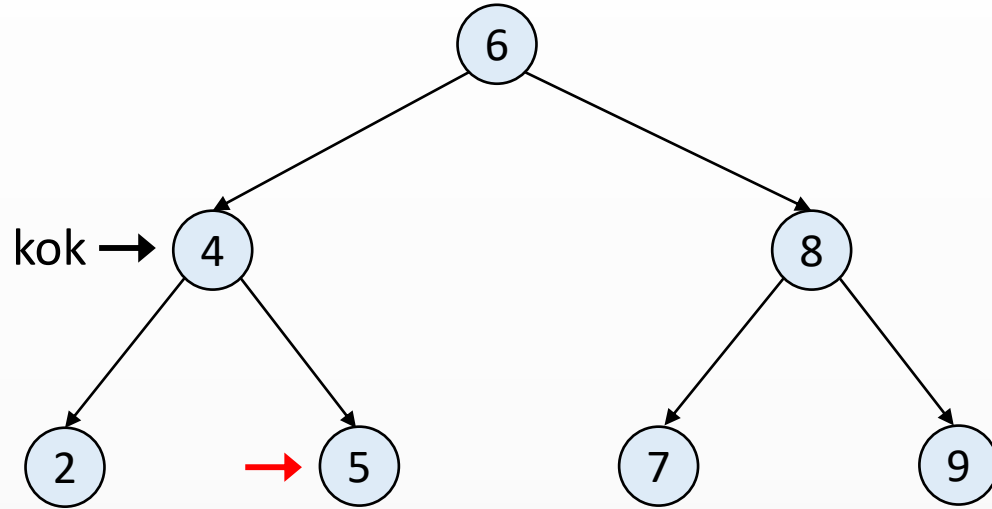


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5

anahtar = 5

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1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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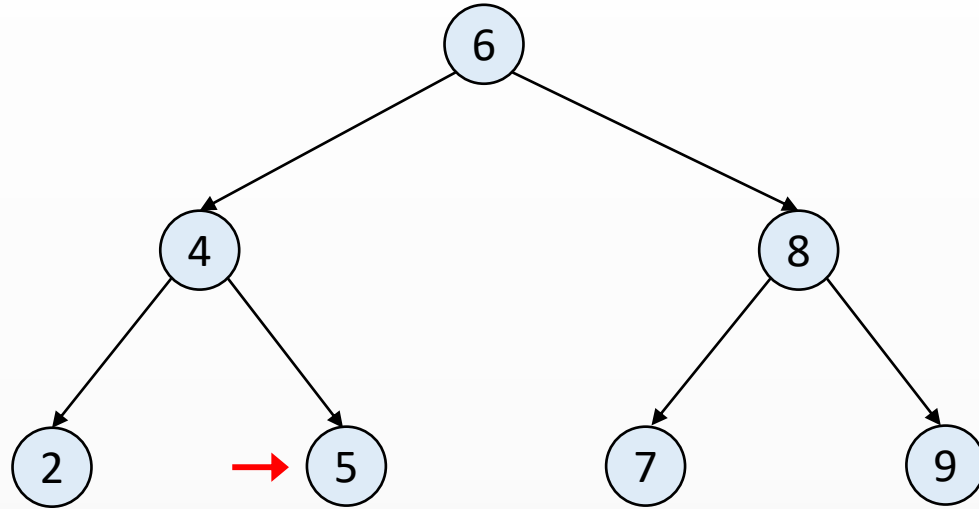


metot çağırımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5

anahtar = 5



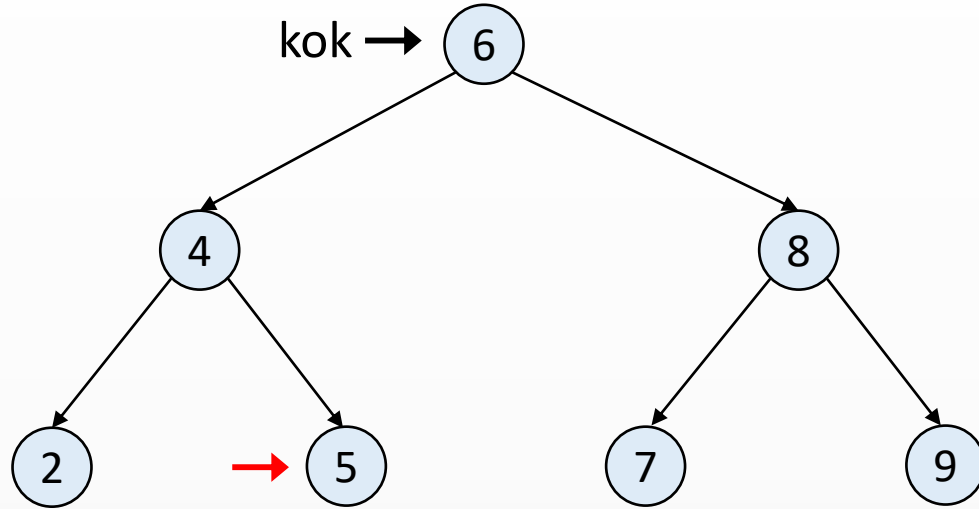
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metot çağırımı	satır no	kok	anahtar
ara	7	6	5

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metot çağırımı	satır no	kok	anahtar
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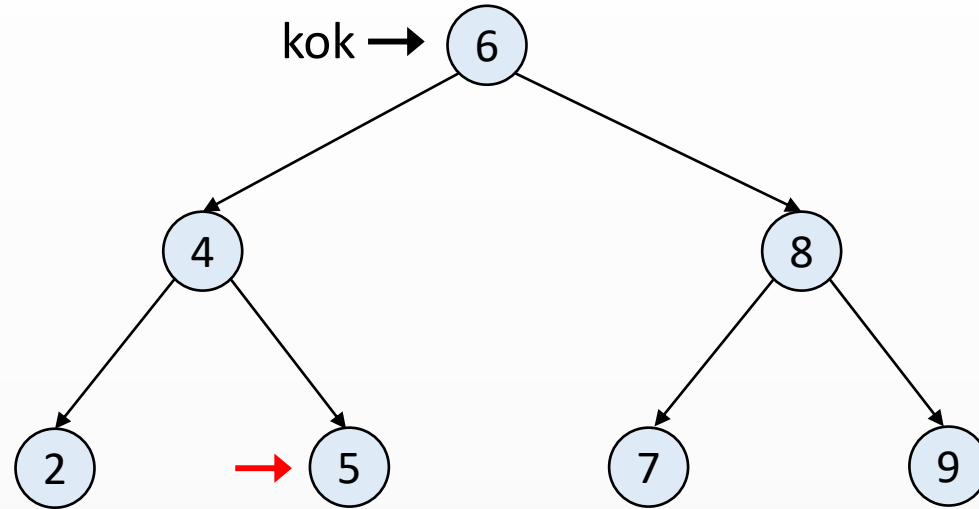


metot çağırımı

satır no

kok

anahtar



anahtar = 5

```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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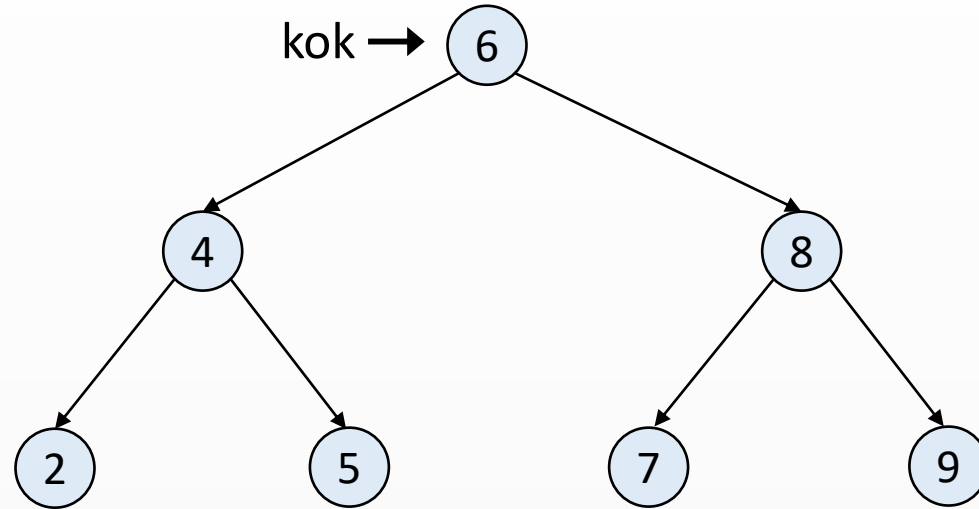


metot çağırımı

satır no

kok

anahtar



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
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```

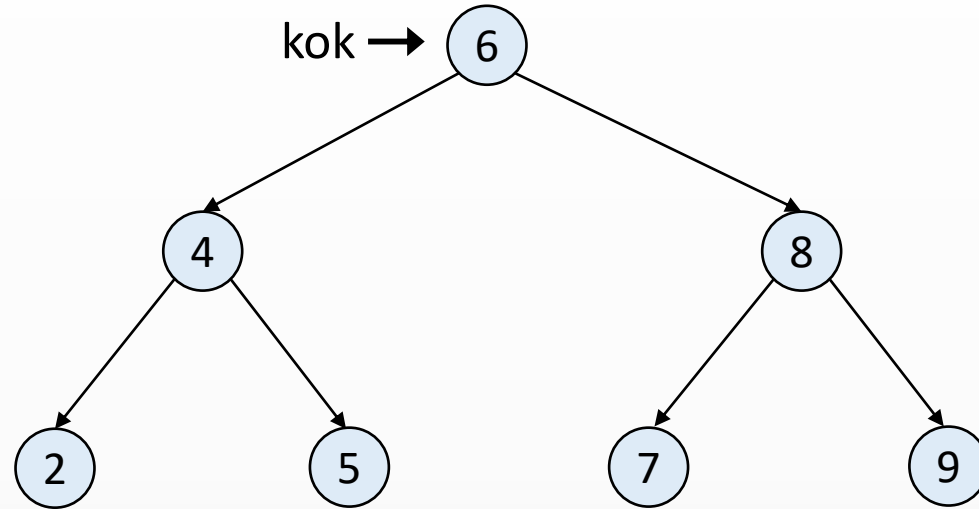


metot çağırımı

satır no

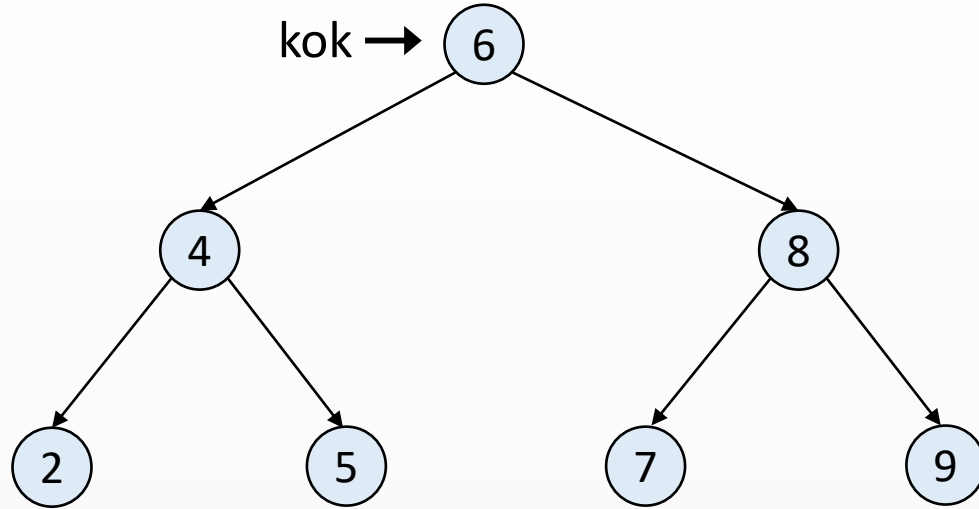
kok

anahtar



anahtar = 10

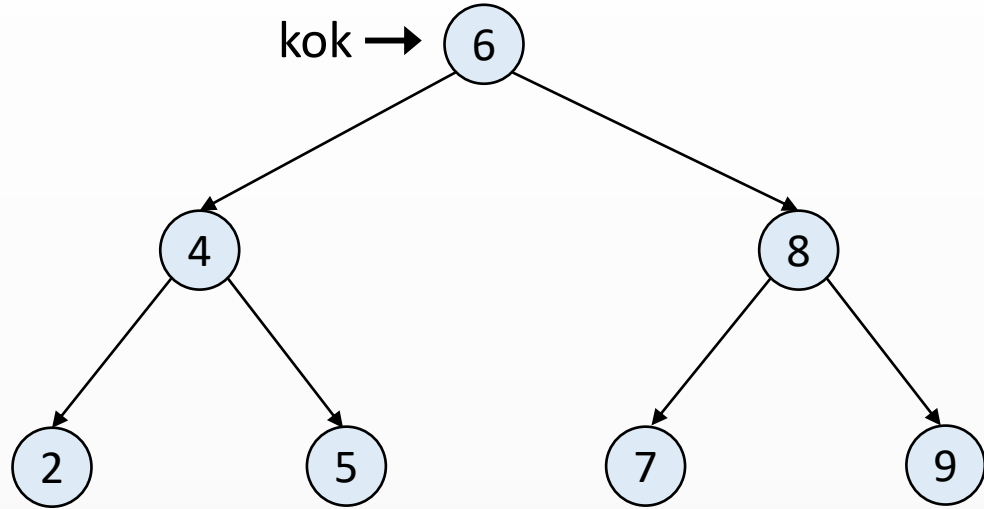
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anahtar = 10

metot çağırımı	satır no	kok	anahtar
ara		6	10

```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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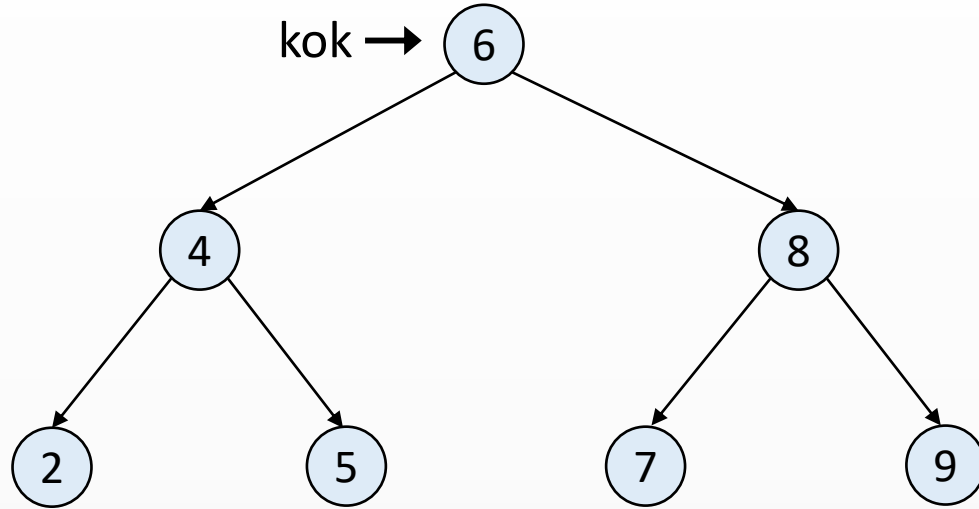


anahtar = 10

metot çağırımı	satır no	kok	anahtar
ara		6	10

```
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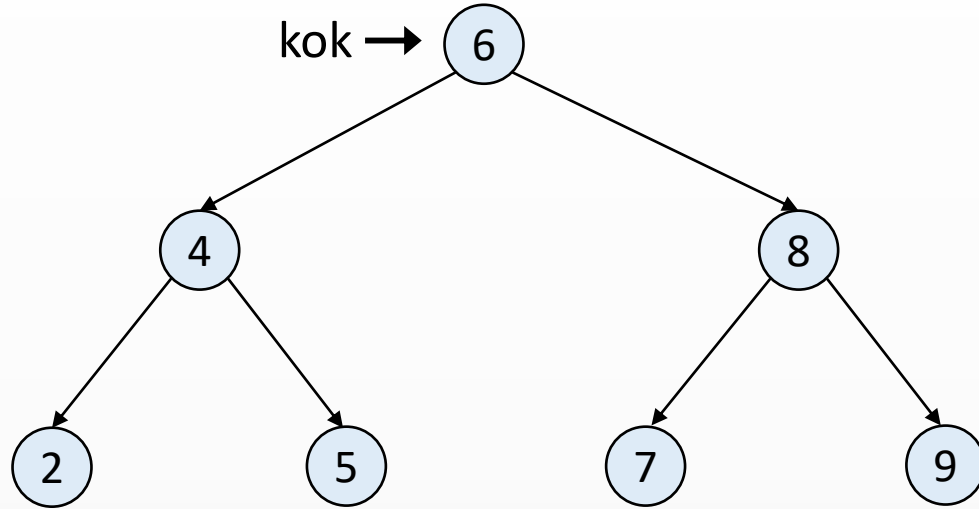




anahtar = 10

metot çağırımı	satır no	kok	anahtar
ara		6	10

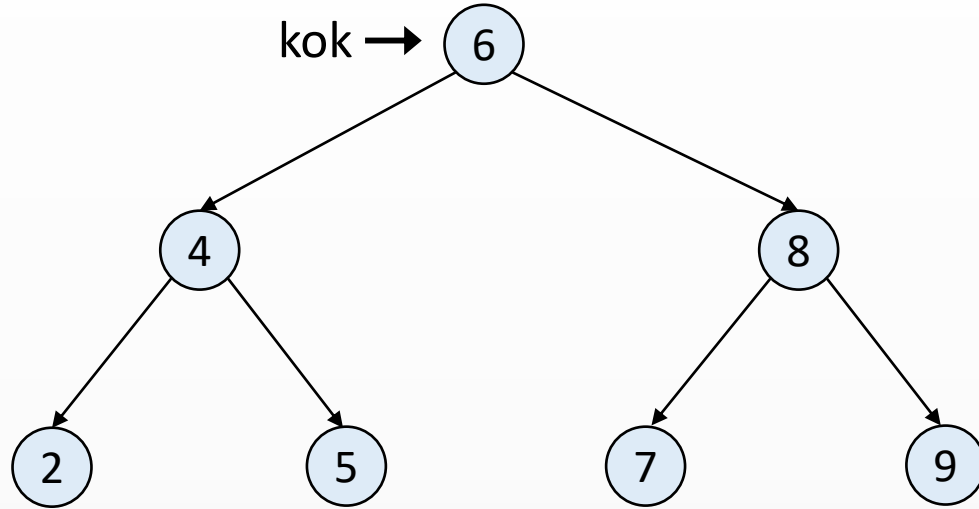
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10 }
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anahtar = 10

metot çağırımı	satır no	kok	anahtar
ara		6	10

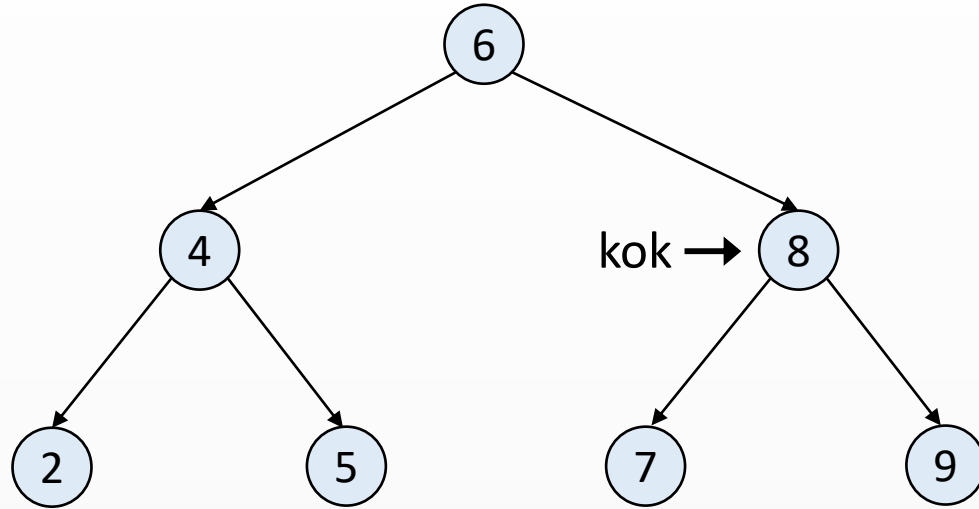
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8     else
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10 }
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anahtar = 10

metot çağırımı	satır no	kok	anahtar
ara	9	6	10

```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```

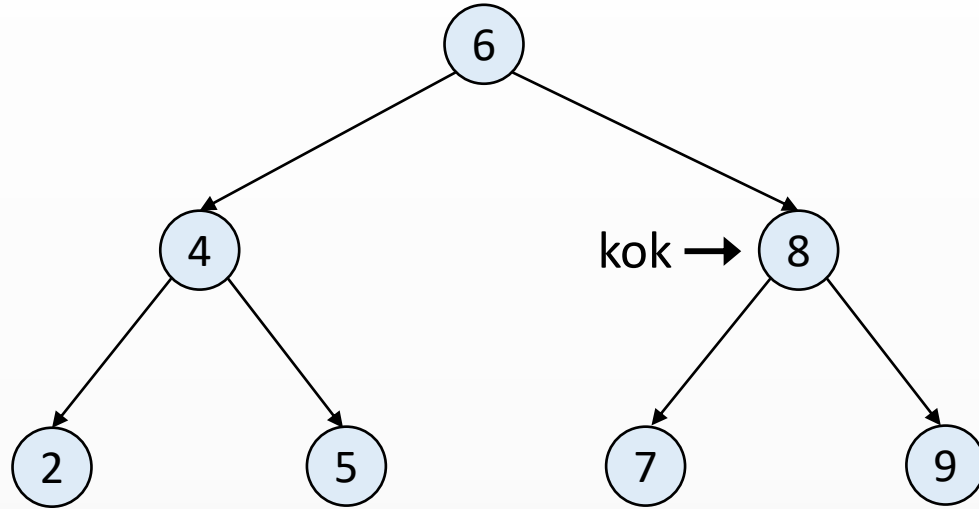


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
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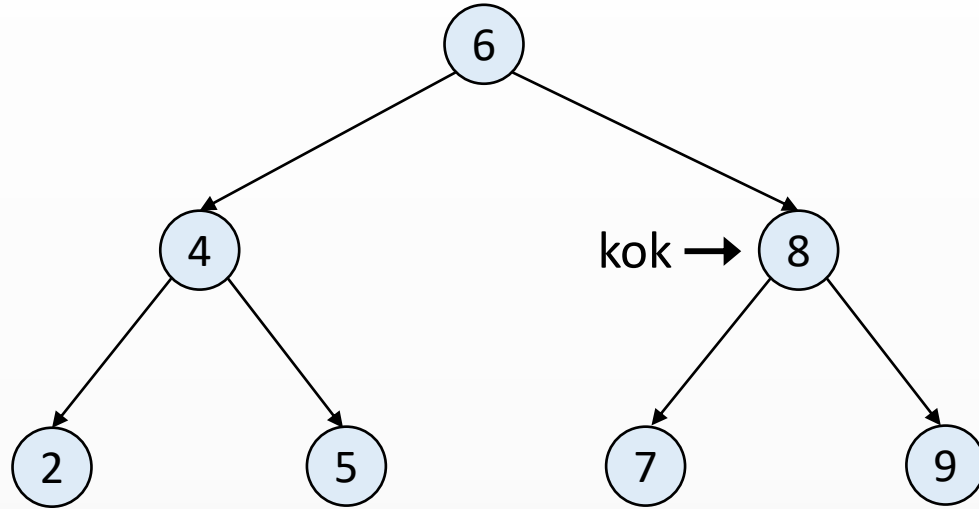


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
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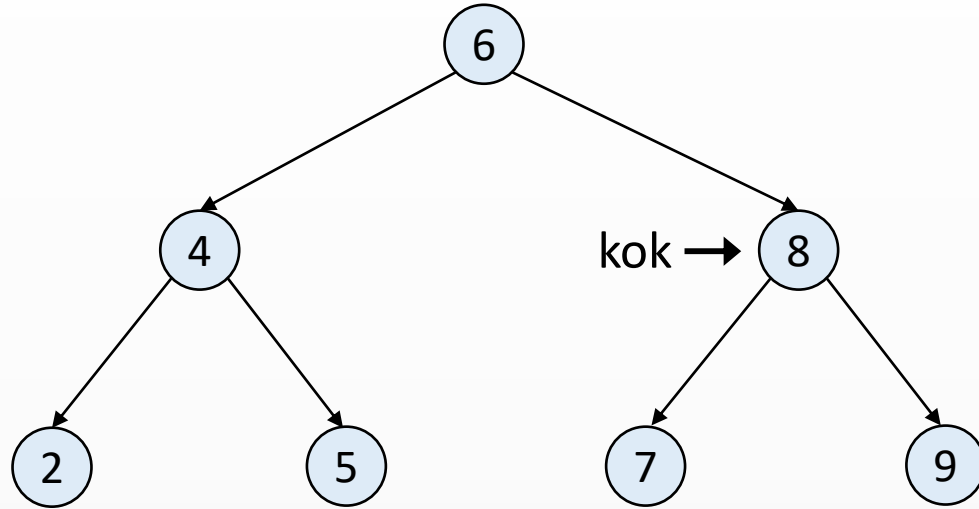


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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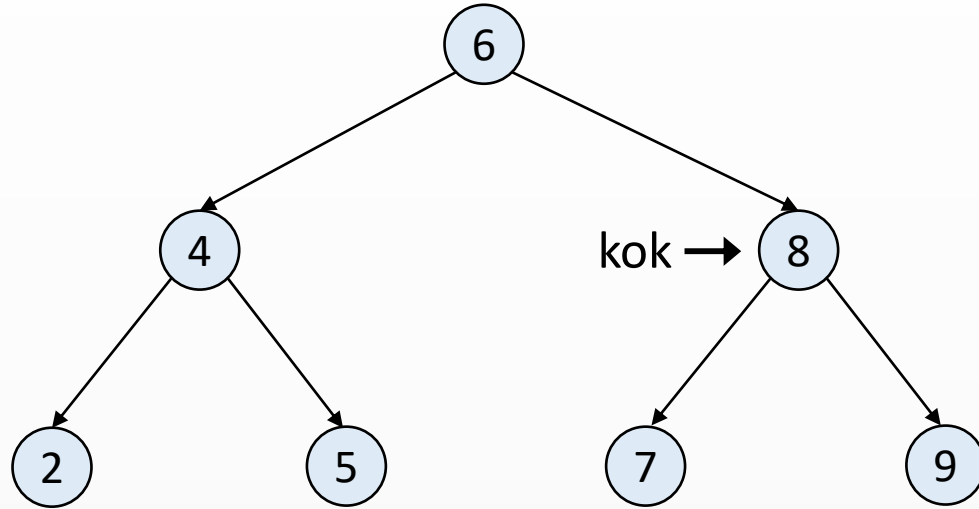


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
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```



anahtar = 10

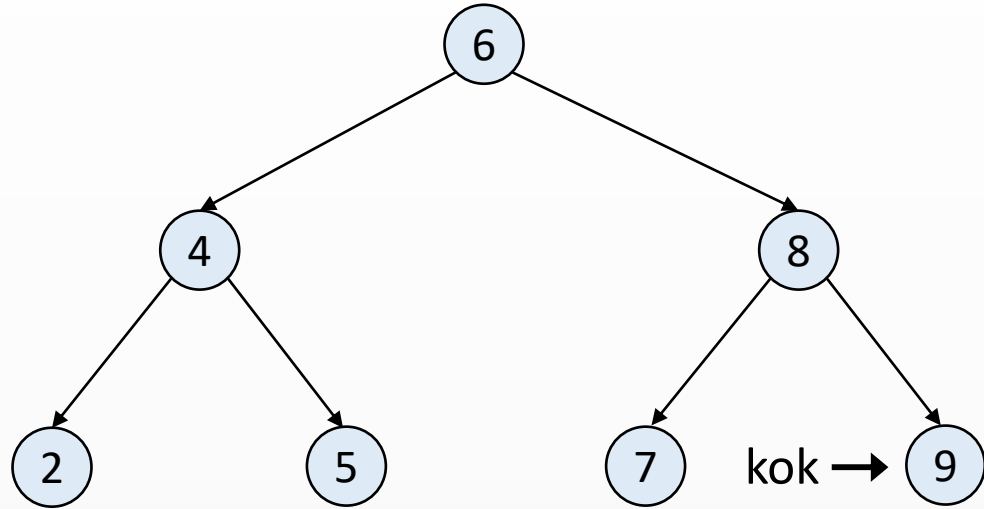


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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8     else
9         return ara(kok.sag, anahtar);
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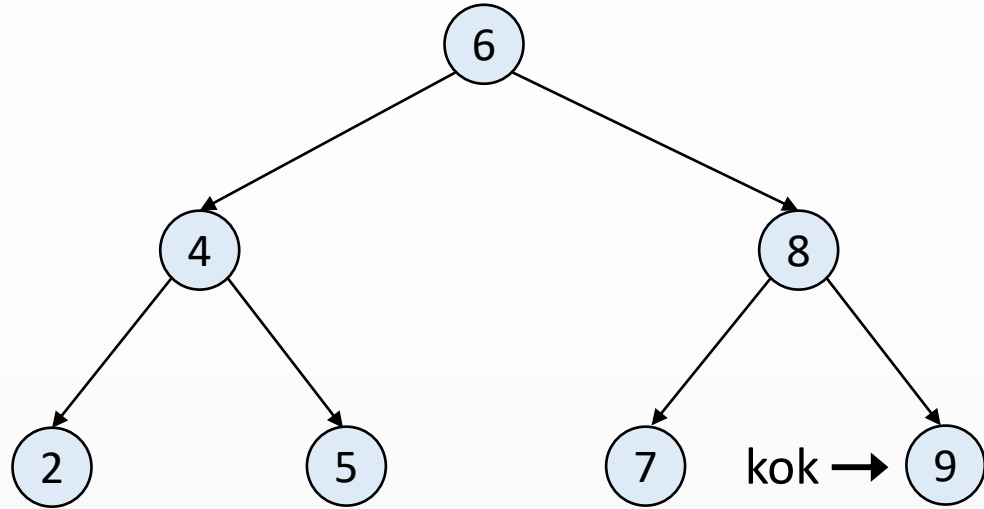
anahtar = 10



metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara		9	10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
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10 }
```

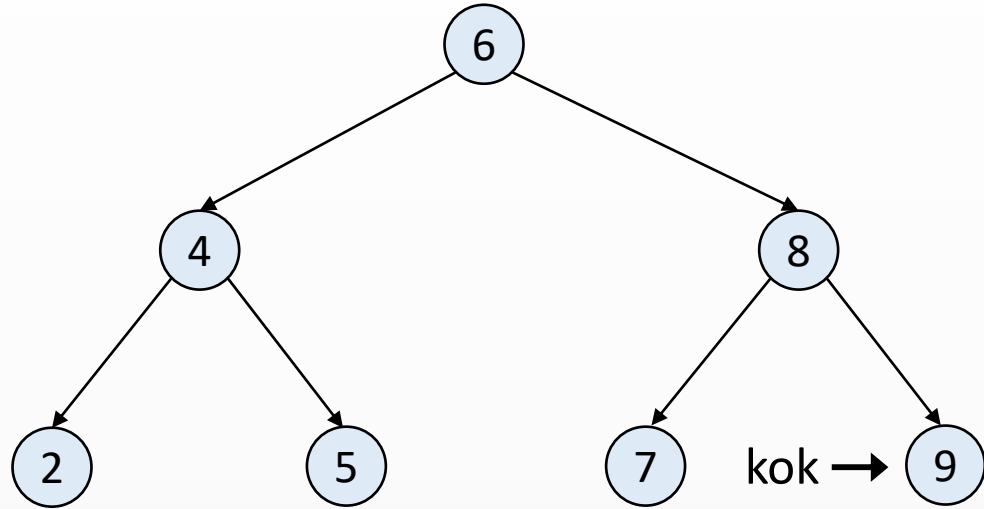


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara		9	10

anahtar = 10



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```

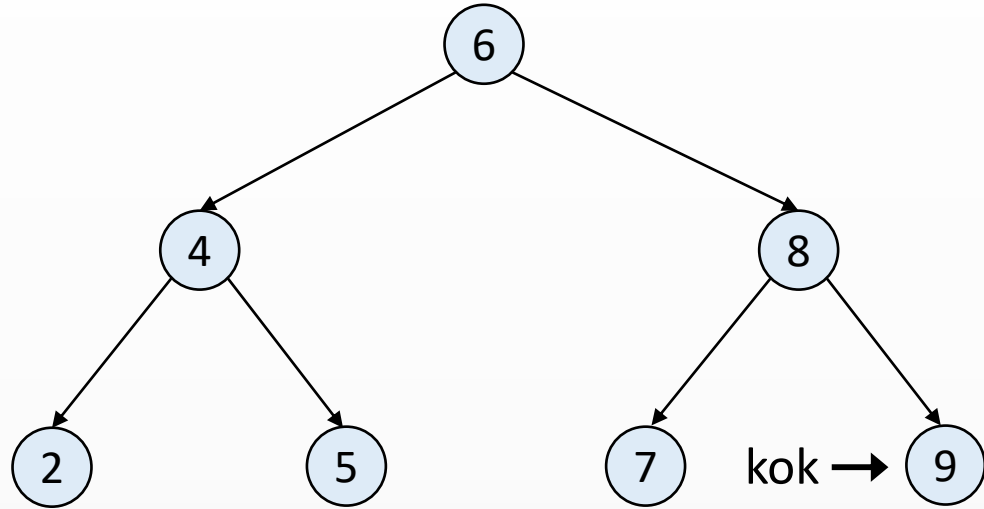


metot çağırımı	satır no	kok	anahtar
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8     else
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10 }
```

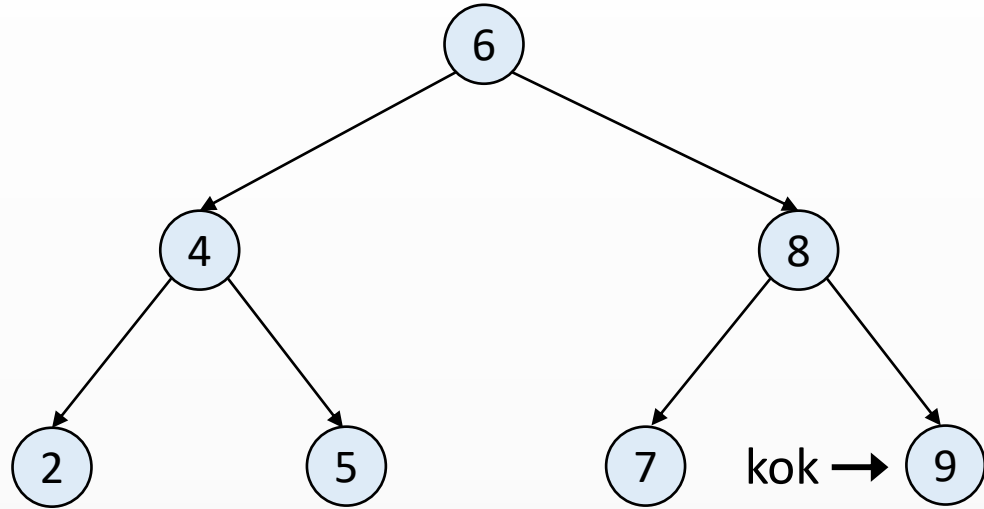


metot çağırımı	satır no	kok	anahtar
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```
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5     }
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7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```

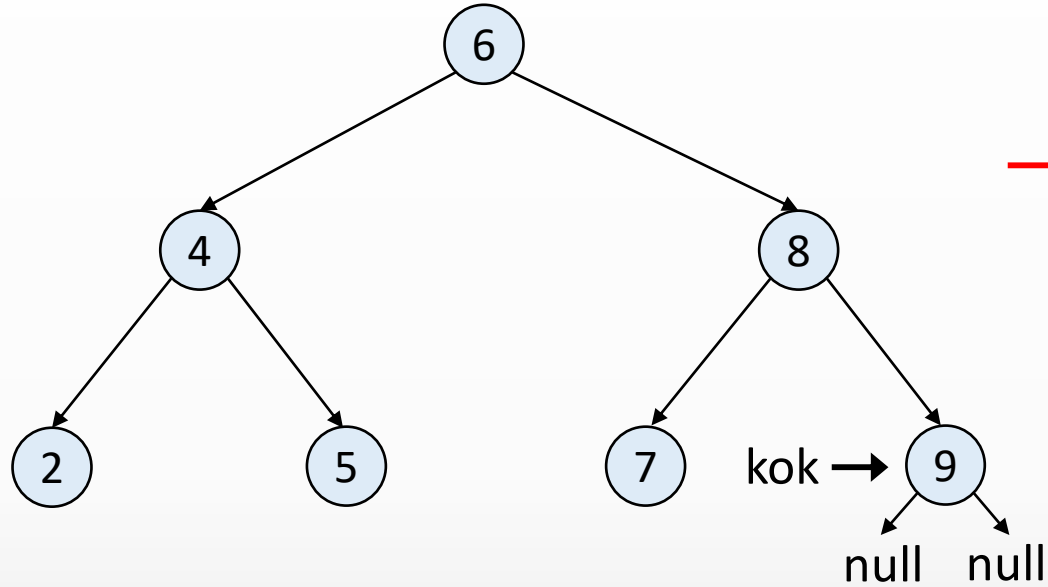


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10

anahtar = 10



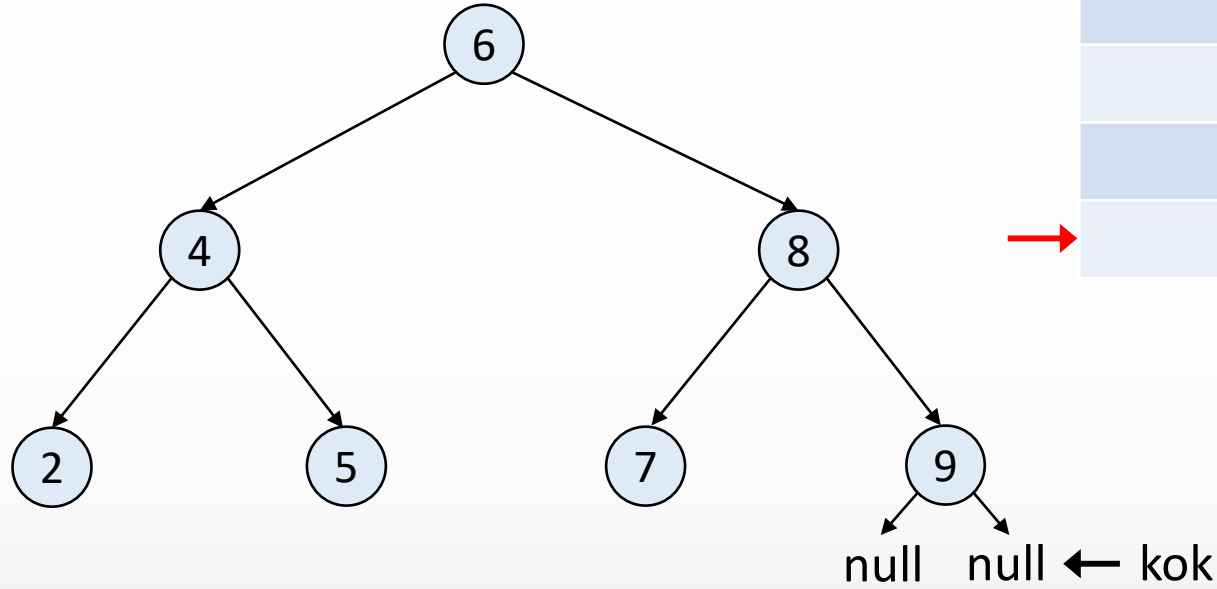
```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
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9         return ara(kok.sag, anahtar);
10 }
```



metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10

anahtar = 10

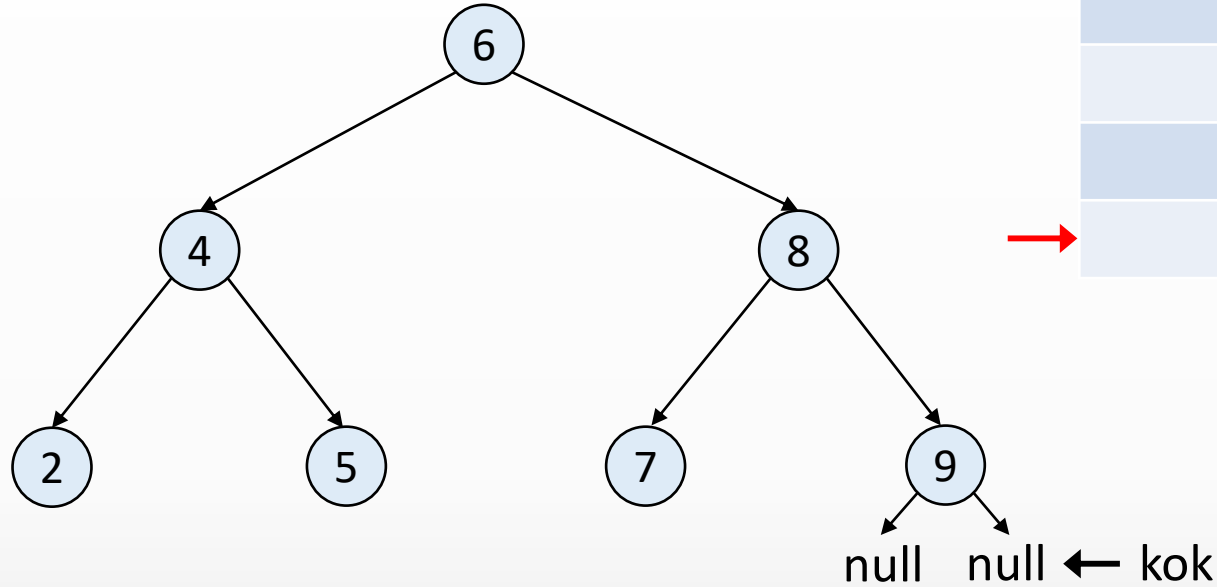
```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```



metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10
ara		null	10

anahtar = 10

```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```

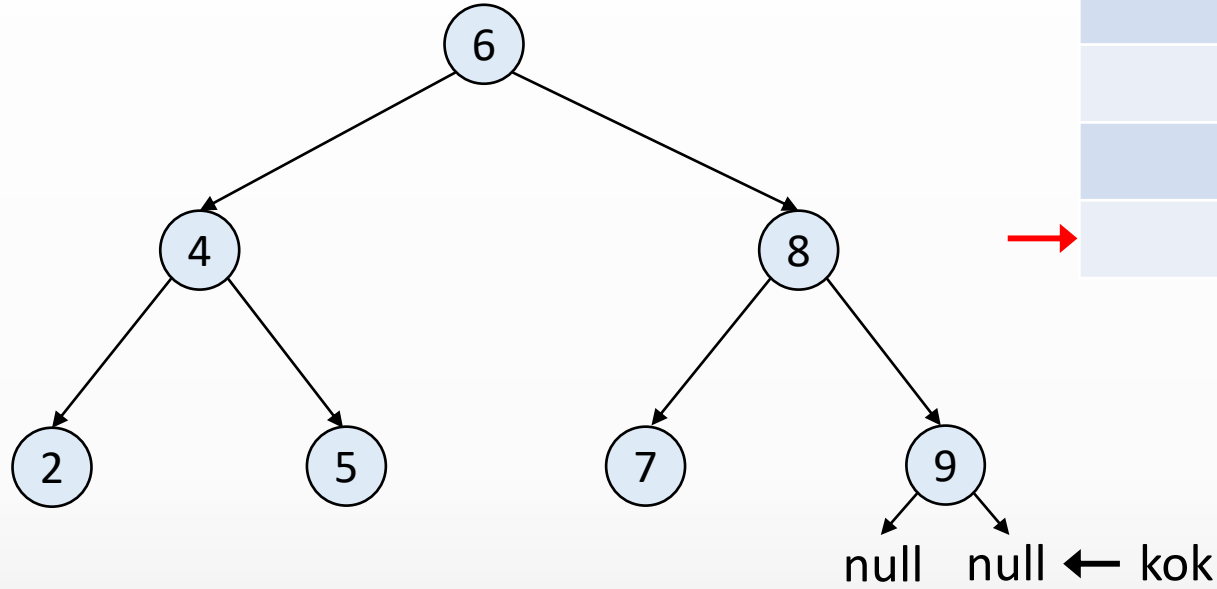


metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10
ara		null	10

anahtar = 10

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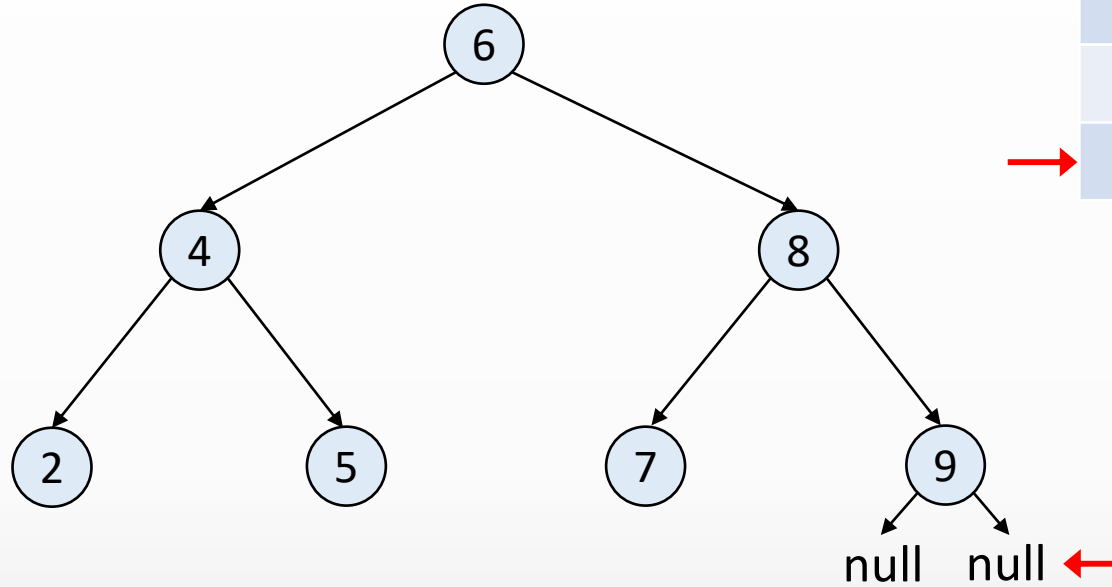




metot çağırımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10
ara		null	10

anahtar = 10

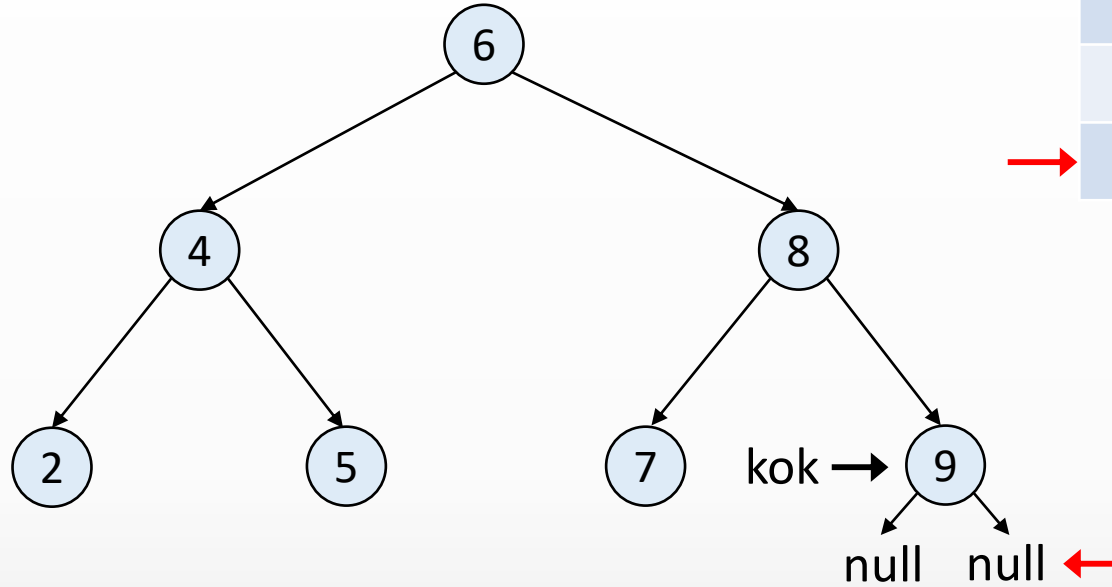
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anahtar = 10

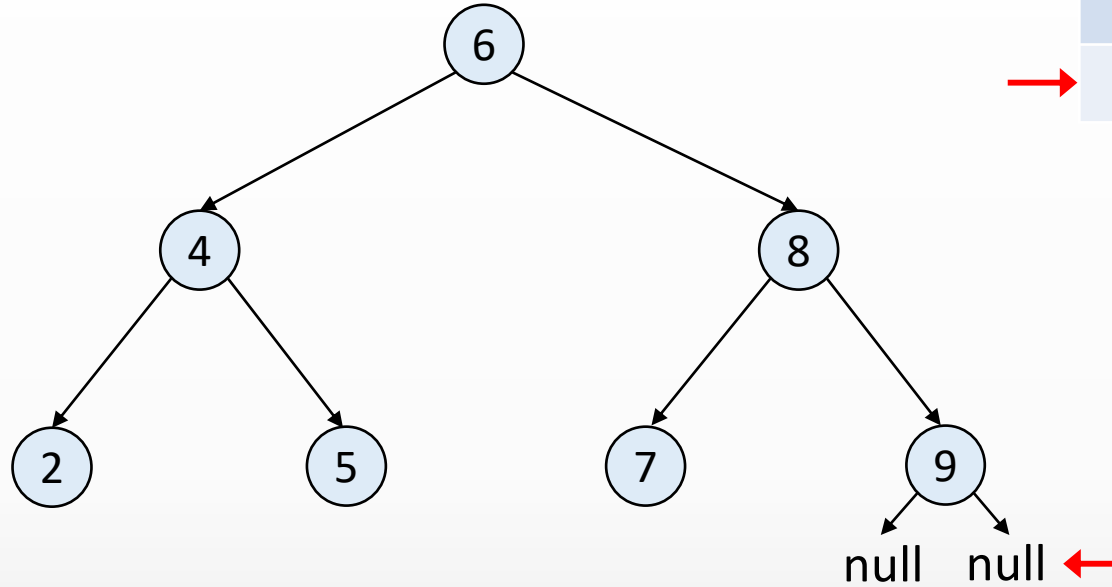
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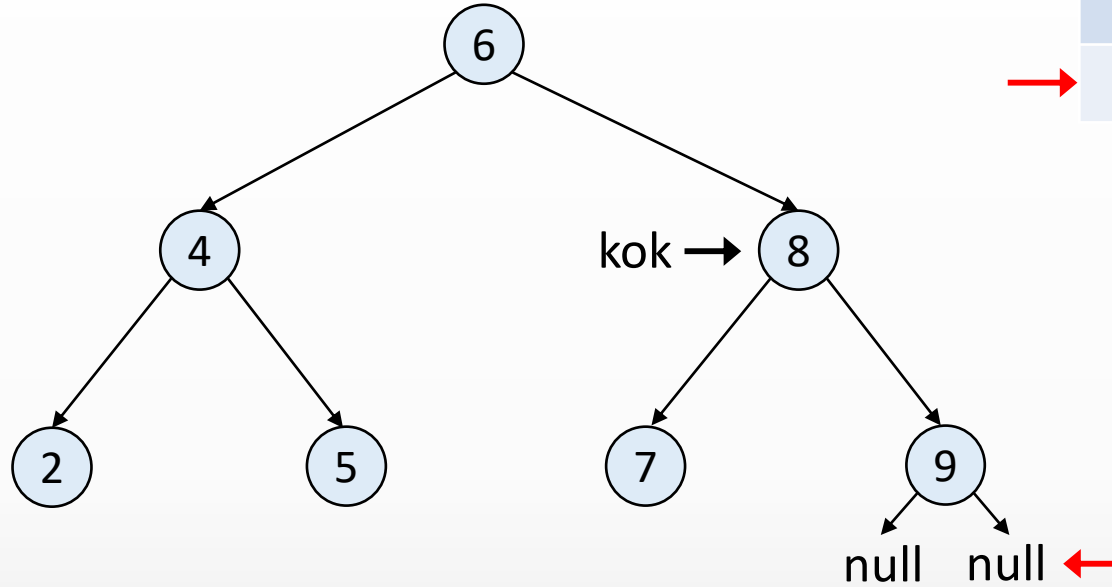
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metot çağırımı	satır no	kok	anahtar
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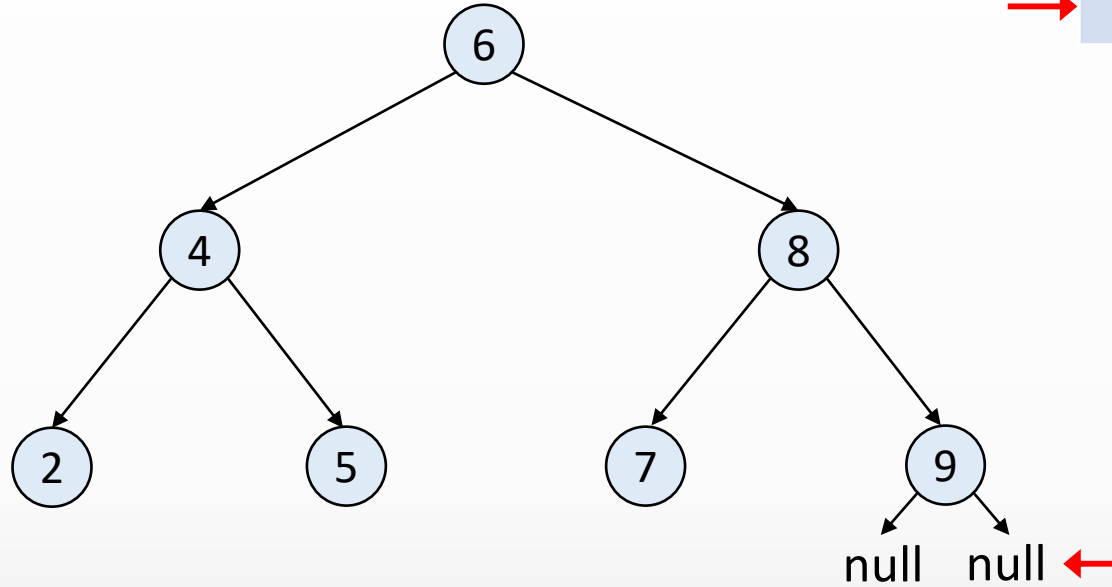
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2 {
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```



metot çağırımı	satır no	kok	anahtar
ara	9	6	10
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anahtar = 10

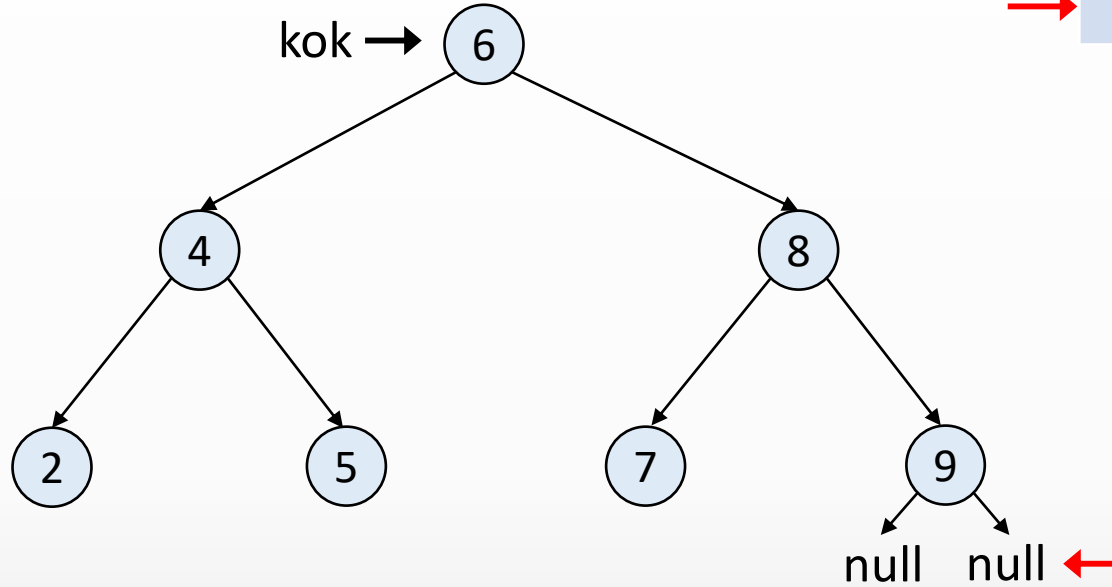
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2 {
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metot çağırımı	satır no	kok	anahtar
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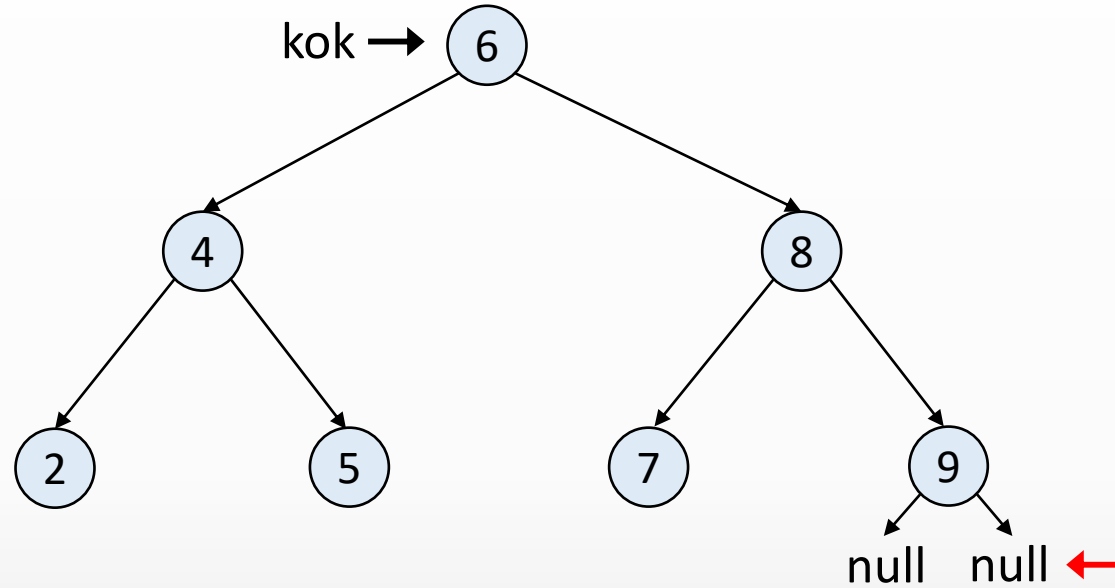


metot çağırımı

satır no

kok

anahtar



```
1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
2 {
3     if(kok == null || kok.veri == anahtar) {
4         return kok;
5     }
6     if(anahtar < kok.veri)
7         return ara(kok.sol, anahtar);
8     else
9         return ara(kok.sag, anahtar);
10 }
```







# Generic İkiliAgacDugum Sınıfı

```
public class İkiliAgacDugum<E extends Comparable<E>> {  
  
    E veri; // Düğümün sakladığı nesne  
    İkiliAgacDugum<E> solCocuk; // Sol çocuk düğümün referansı  
    İkiliAgacDugum<E> sagCocuk; // Sağ çocuk düğümün referansı  
  
    public İkiliAgacDugum(E veri) {  
        this.veri = veri; // Düğümün verisini ata  
        this.solCocuk = null; // Sol çocuk başlangıçta boş  
        this.sagCocuk = null; // Sağ çocuk başlangıçta boş  
    }  
}
```



# Maksimum Değere Sahip Düğüm

```
IkiliAgacDugum<E> maxDeger(IkiliAgacDugum<E> dugum) {  
  
    while (dugum.sagCocuk != null) {  
        // Düğümü sol çocuğa taşı ve en küçük değeri ara  
        dugum = dugum.sagCocuk;  
    }  
    return dugum; // En küçük değeri döndür  
}
```



# Minimum Değere Sahip Düğüm

```
IkiliAgacDugum<E> minDeger(IkiliAgacDugum<E> dugum) {  
  
    while (dugum.solCocuk != null) {  
        // Düğümü sol çocuğa taşı ve en küçük değeri ara  
        dugum = dugum.solCocuk;  
    }  
    return dugum; // En küçük değeri döndür  
}
```

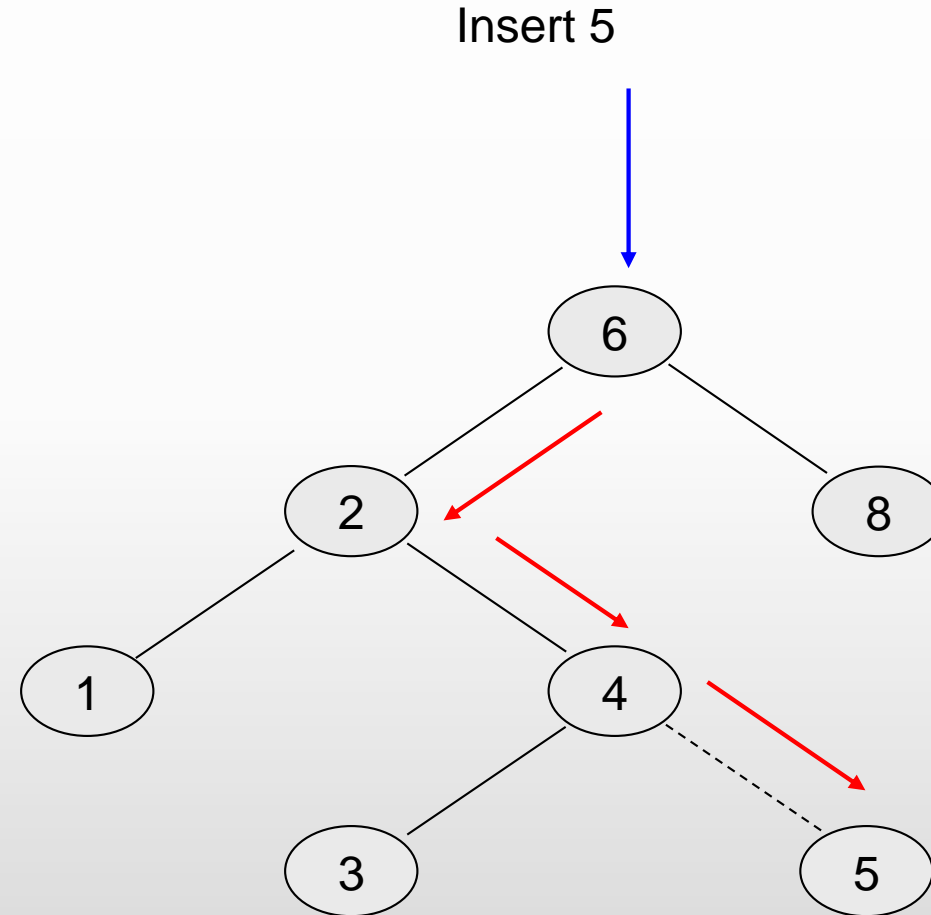


# Öğe Arama

```
boolean ara(IkiliAgacDugum<E> kok, E veri) {  
    if (kok == null) { return false; }  
    if (veri == kok.veri) {  
        System.out.println("Ağaçta " + kok.veri + " bulundu.");  
        return true;  
    } else if (veri.compareTo(kok.veri) < 0) {  
        return ara(kok.solCocuk, veri); // sol alt ağaçta ara  
    } else {  
        return ara(kok.sagCocuk, veri); // sağ alt ağaçta ara  
    }  
}
```



# Öğ ekleme



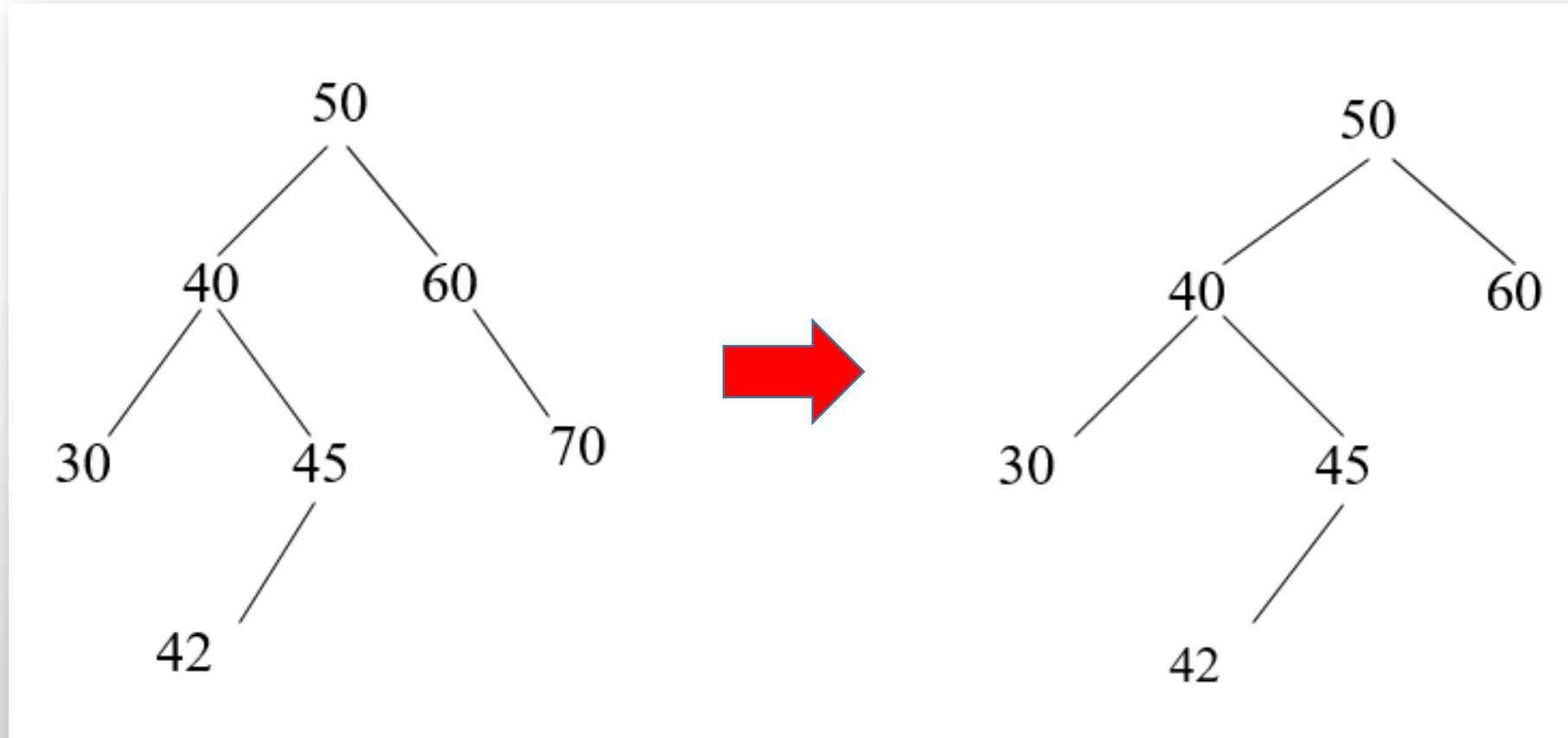


# Öğe Ekleme

```
IkiliAgacDugum<E> ekle(IkiliAgacDugum<E> kok, E veri) {  
    if (kok == null) {  
        kok = new IkiliAgacDugum<E>(veri);  
        System.out.println("Ağaca eklendi: " + kok.veri);  
        return kok;  
    }  
    if (veri.compareTo(kok.veri) < 0) {  
        kok.solCocuk = ekle(kok.solCocuk, veri); // sol alt ağaca  
    } else if (veri.compareTo(kok.veri) > 0) {  
        kok.sagCocuk = ekle(kok.sagCocuk, veri); // sağ alt ağaca  
    }  
    return kok;  
}
```



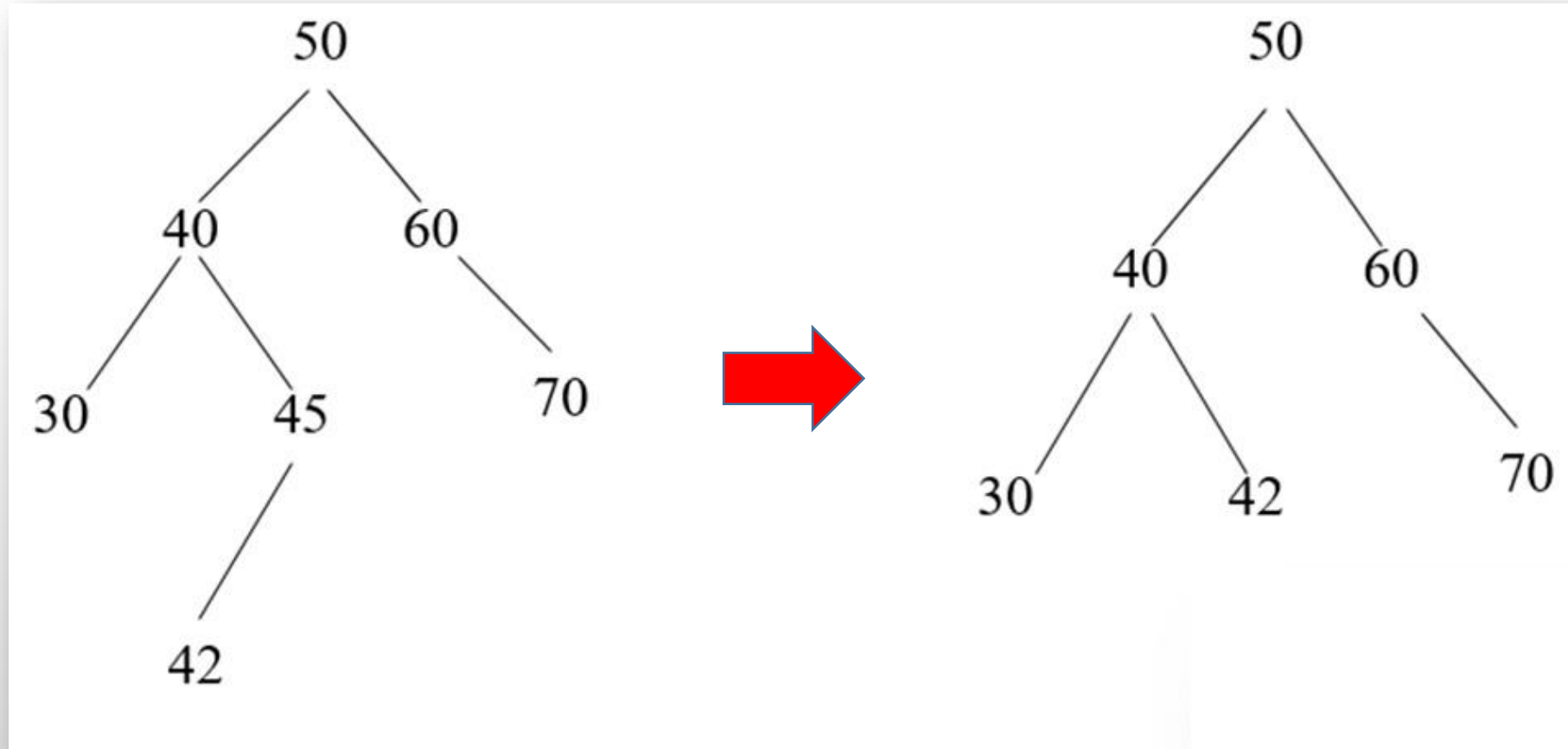
# Öge Silme – Yaprak Düğüm





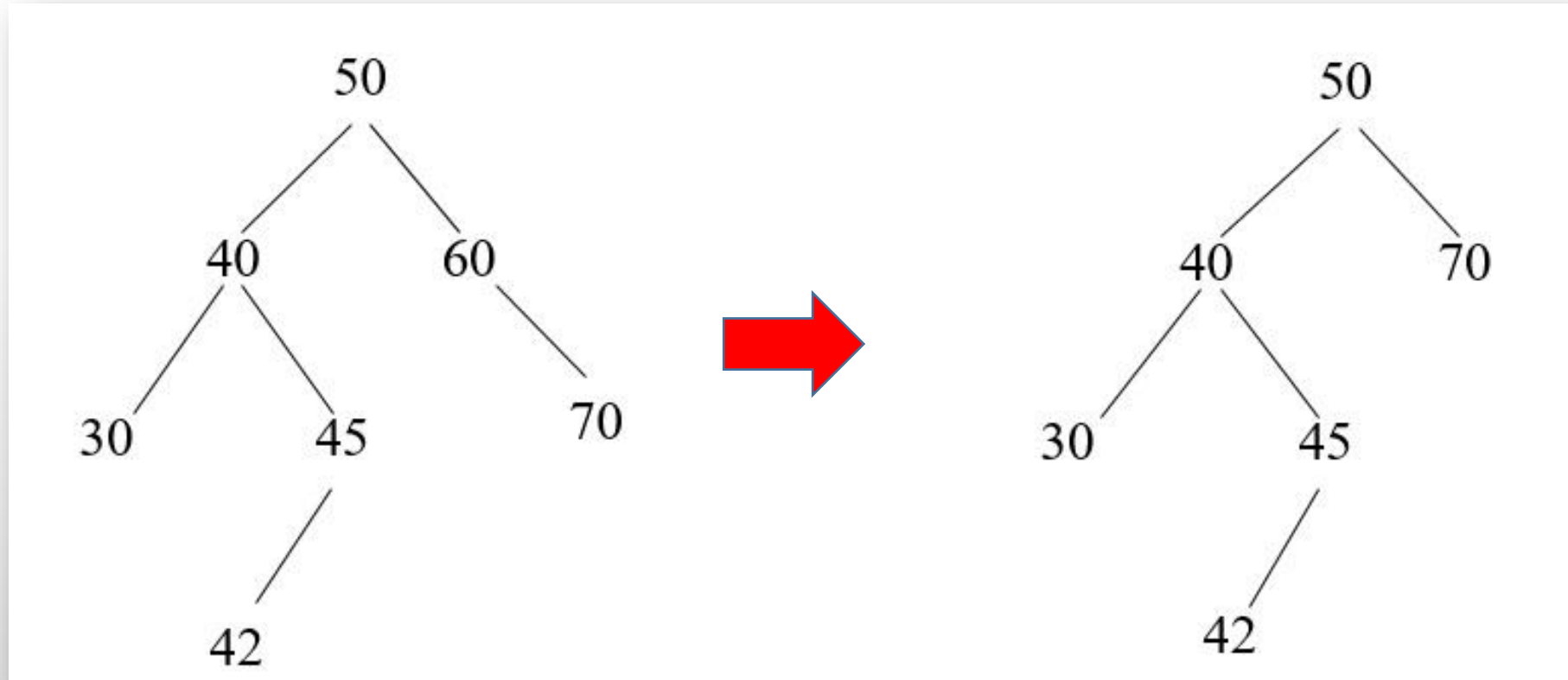


# Öge Silme – Sol Çocuğu var



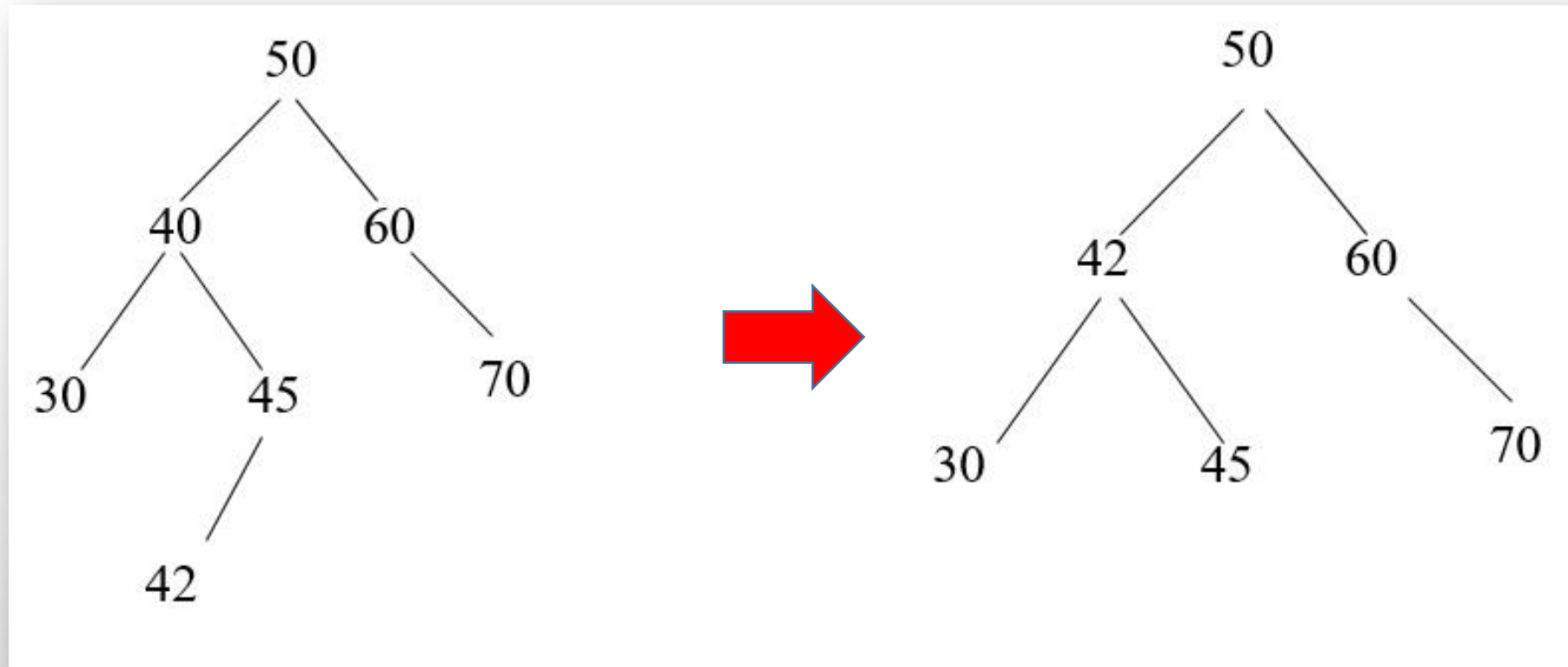


# Öge Silme – Sağ Çocuğu var





# Öge Silme – Sol ve Sağ Çocuğu var





# Öğ e Silme

```
IkiliAgacDugum<E> sil(IkiliAgacDugum<E> kok, E veri) {  
    if (kok == null) { return kok; }  
    if (veri.compareTo(kok.veri) < 0) {  
        kok.solCocuk = sil(kok.solCocuk, veri); // soldan devam  
    } else if (veri.compareTo(kok.veri) > 0) {  
        kok.sagCocuk = sil(kok.sagCocuk, veri); // sağdan devam  
    } else if (kok.solCocuk != null && kok.sagCocuk != null) {  
        kok.veri = minDeger(kok.sagCocuk).veri; // sonraki düğümü bul  
        kok.sagCocuk = sil(kok.sagCocuk, kok.veri); // sağdan devam  
    } else if (kok.solCocuk == null) {  
        return kok.sagCocuk; // sol çocuk yoksa, sağ çocuğu geri döndür  
    } else if (kok.sagCocuk == null) {  
        return kok.solCocuk; // sağ çocuk yoksa, sol çocuğu geri döndür  
    }  
    return kok;  
}
```

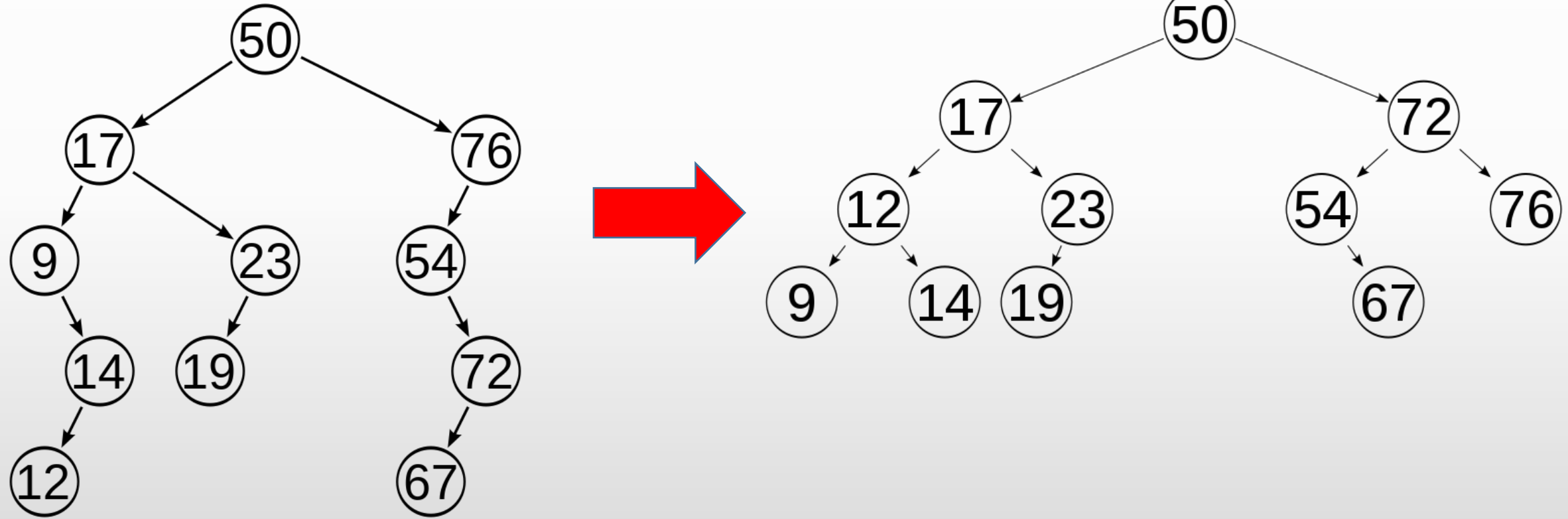


# İkili Arama Ağacı İşlemlerinin Analizi

- Bir işlemin maliyeti, son erişilen düğümün derinliği ile doğru orantılıdır.
- İyi Dengelenmiş Ağaç (Best Case):
  - İşlemler logaritmik maliyetle gerçekleşir.
  - Derinlik dengeli olduğu için erişim hızlıdır.
- Devrik Ağaç (Worst Case):
  - İşlemler lineer maliyetle gerçekleşebilir.
  - Derinlik arttıkça erişim maliyeti kötüleşir.

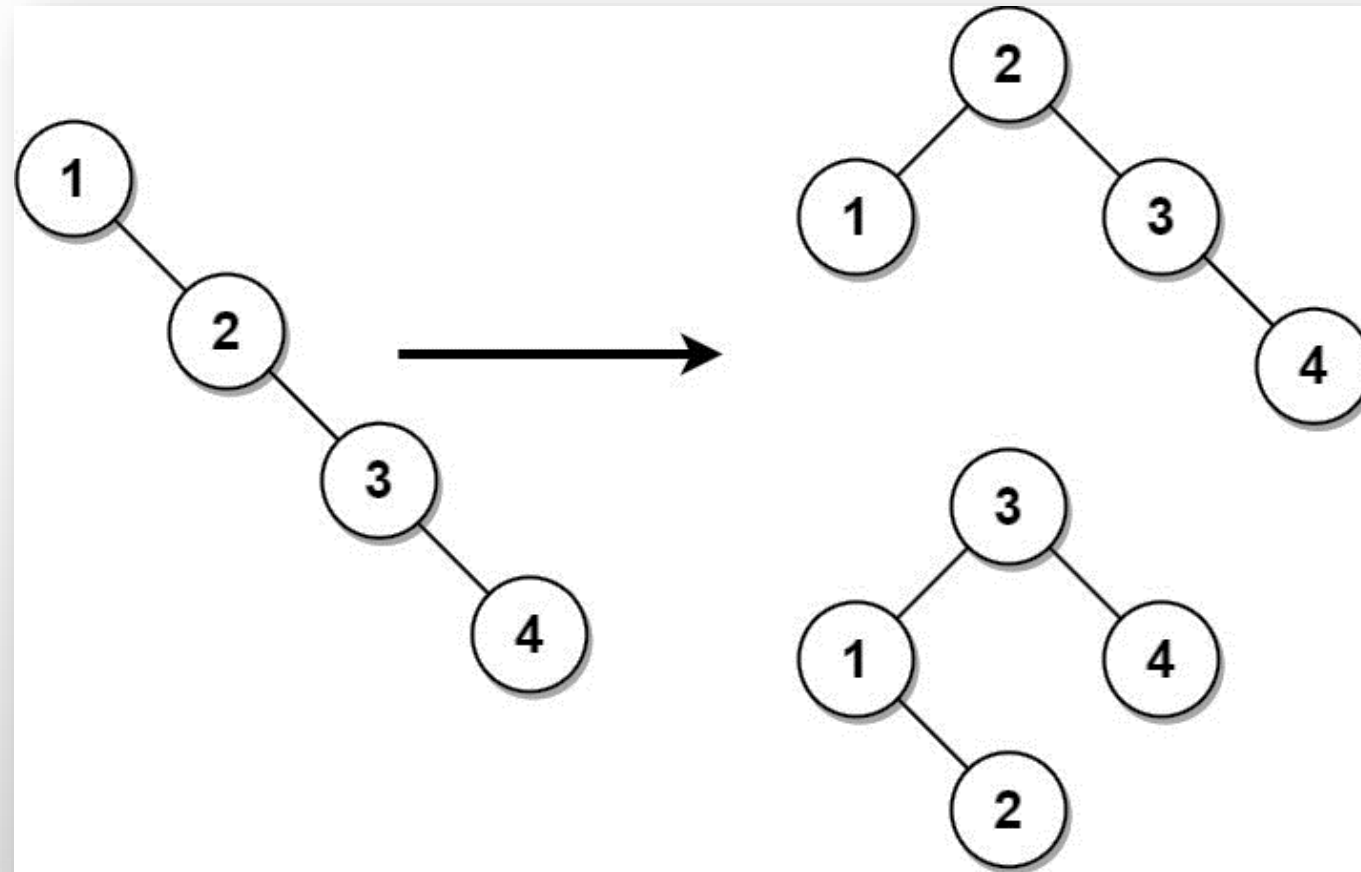


# Dengeleme





# Dengeleme









# Ogrenci Sınıfı

```
public class Ogrenci {  
  
    int ogrenciNo;  
    String adSoyad;  
  
    public Ogrenci(int ogrenciNo, String adSoyad) {  
        this.ogrenciNo = ogrenciNo;  
        this.adSoyad = adSoyad;  
    }  
}
```



# OgrenciDugum Sınıfı

```
public class OgrenciDugum {  
  
    Ogrenci ogr;           // Düğümün içerdiği veri  
    OgrenciDugum solCocuk; // Sol çocuk düğümün referansı  
    OgrenciDugum sagCocuk; // Sağ çocuk düğümün referansı  
  
    public OgrenciDugum(Ogrenci ogr) {  
        this.ogr = ogr;           // Düğümün verisini ata  
        this.solCocuk = null;     // Sol çocuk başlangıçta boş  
        this.sagCocuk = null;     // Sağ çocuk başlangıçta boş  
    }  
}
```



# Öğrenci Ekleme

```
OgrenciDugum ekle(OgrenciDugum kok, Ogrenci ogr) {  
  
    if (kok == null){ kok = new OgrenciDugum(ogr); return kok;}  
  
    if (kok.ogr.ogrenciNo > ogr.ogrenciNo) {  
        kok.solCocuk = ekle(kok.solCocuk, ogr); // soldan devam  
    }  
    else if (kok.ogr.ogrenciNo < ogr.ogrenciNo) {  
        kok.sagCocuk = ekle(kok.sagCocuk, ogr); // sağdan devam  
    }  
    return kok;  
}
```



# Öğrenci Arama

```
boolean ara(OgrenciDugum kok, int numara) {  
  
    if (kok == null) { return false; }  
  
    if (numara == kok.ogr.ogrenciNo) {  
        System.out.println(kok.ogr.ogrenciNo + " bulundu.");  
        return true;  
    } else if (kok.ogr.ogrenciNo > numara) {  
        return ara(kok.solCocuk, numara); // soldan devam  
    } else {  
        return ara(kok.sagCocuk, numara); // sağdan devam  
    }  
}
```



SON