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.

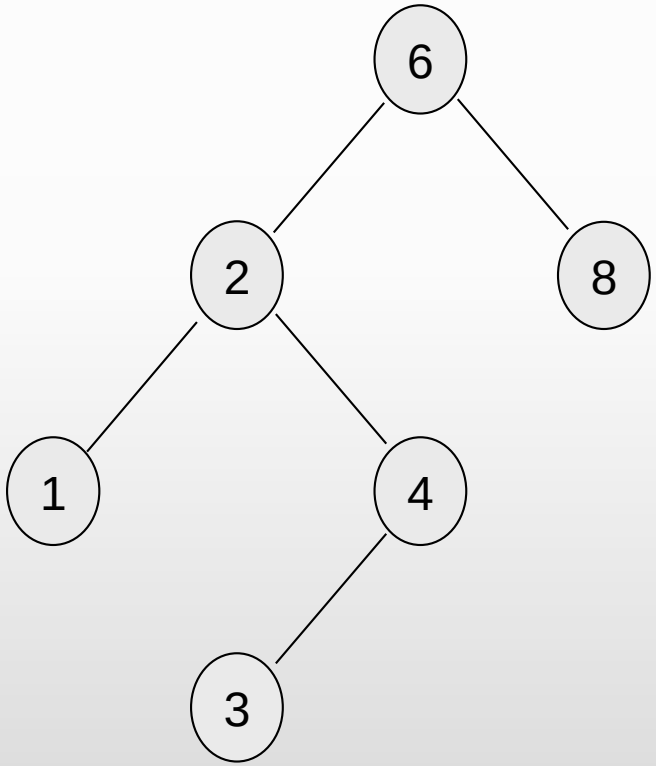
Temel İşlemler

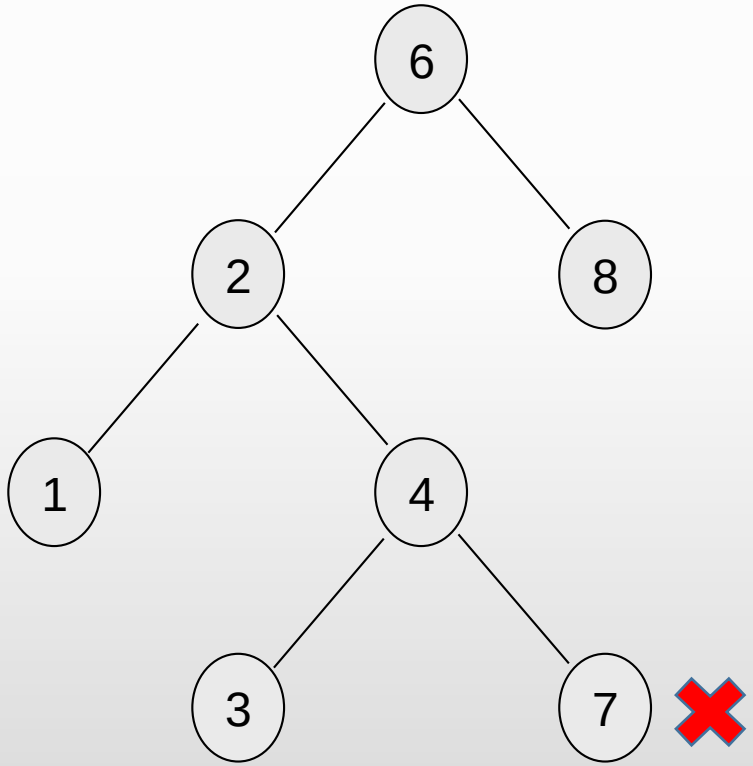
- **Ekleme (Insertion):** Bir öğeyi ağaca ekler.
- **Arama (Search):** Belirli bir anahtarla öğeyi arar ve döndürür.
- **Silme (Deletion):** Belirli bir anahtara sahip öğeyi ağaçtan çıkarır.
- **Gezinme (Traversal):** Ağaç içindeki öğeleri belirli bir sırayla gezme.

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





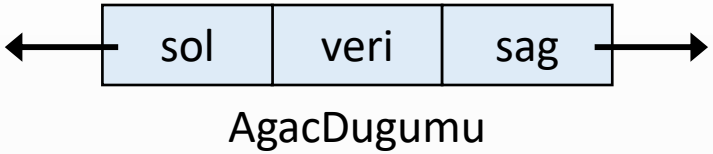
Kırmızı-Siyah Ağaçlar

- 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

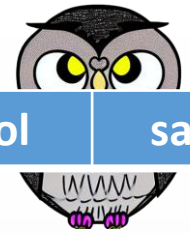
- Her düğümün denge faktörü değeri vardır.
- Denge faktörü, sol ve sağ alt ağaçların yükseklik farkını temsil eder.
- Her düğümün denge faktörü -1, 0 veya 1 olmalıdır.
- Ağaç dengeli olduğunda, her düğümün alt ağaçları da dengelidir.

Ağaç Düğümü Yapısı



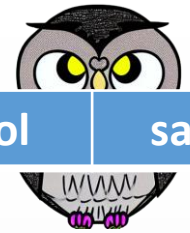

```
public class AgacDugumu {
  private int veri;
  private AgacDugumu sol;
  private AgacDugumu sag;

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

İkili Arama Ağacına Öğe Eklenmesi



metot çağrımı	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 }
```



metot çağrımı	satır no	kok	sonuc	sol	sag

kok → null

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

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

kok → null

deger = 5

```
 1 public AgacDugumu ekle(AgacDugumu kok, int deger)
 2 {
 3   if(kok == null) {
 4     kok = new AgacDugumu(deger);
 5     return kok;
 6   }
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 8     kok.sol = ekle(kok.sol, deger);
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metot çağrımı	satır no	kok	sol	sag	deger
ekle		null	null	null	5

kok → null

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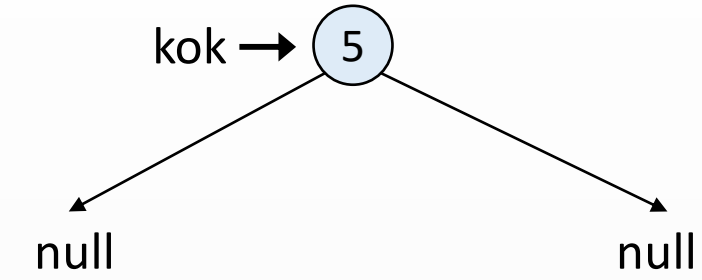

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	null	null	5

```
deger = 5
```

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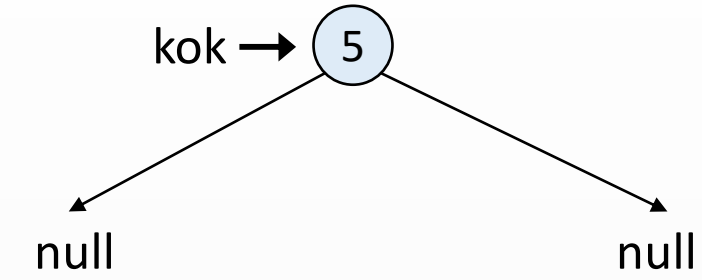

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	null	null	5

```
deger = 5
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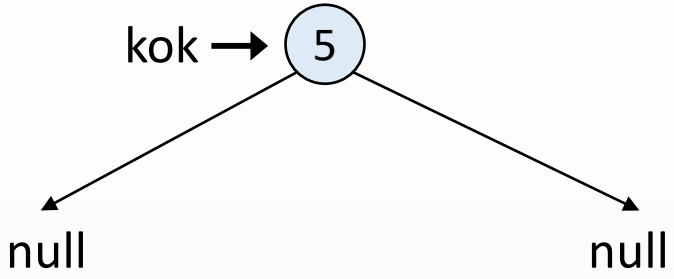

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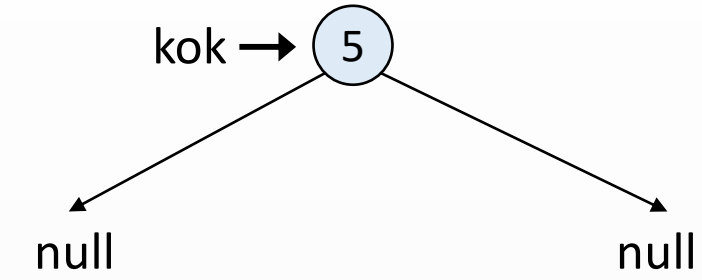

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	null	null	3

```
deger = 3
```

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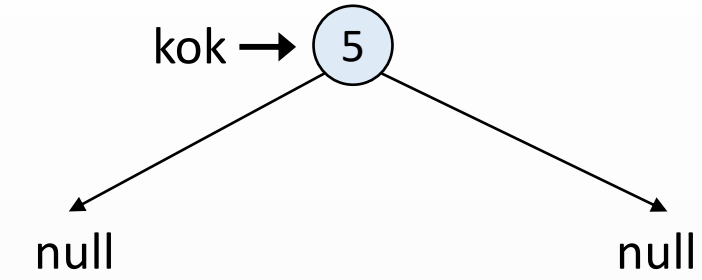

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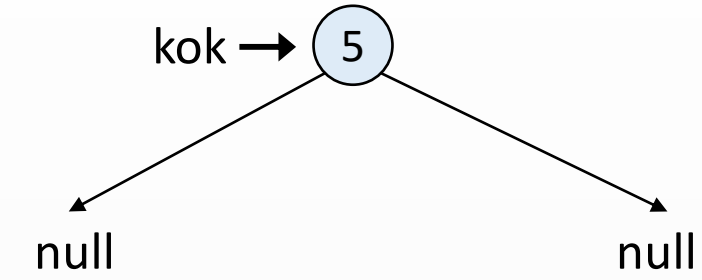

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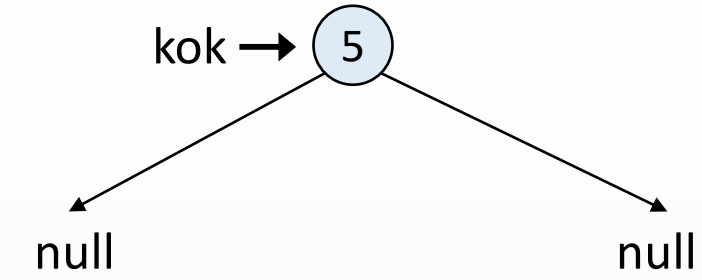

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3

```
deger = 3
```

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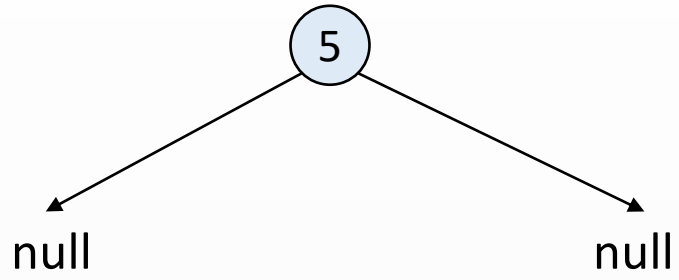

kok → null

deger = 3

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

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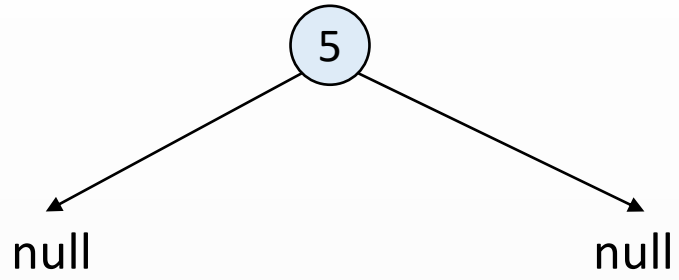

kok → null

deger = 3

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

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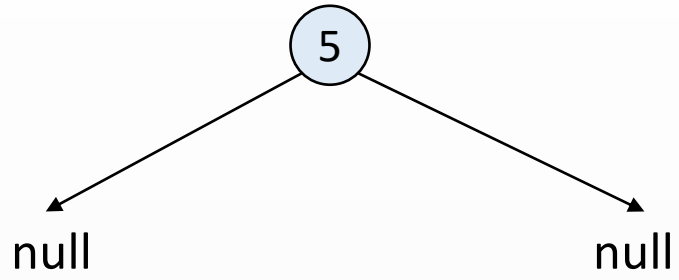
metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		null	null	null	3



kok → null

deger = 3

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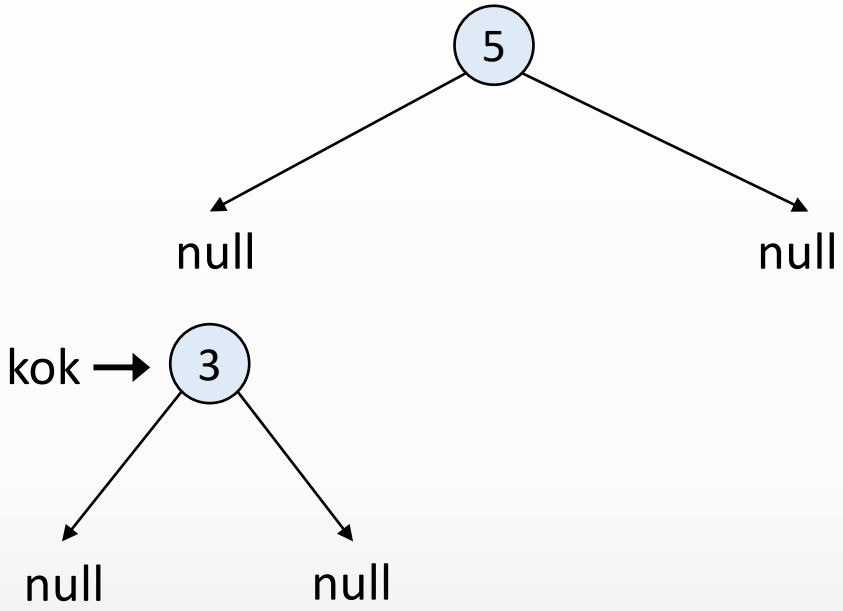

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		3	null	null	3

```
deger = 3
```

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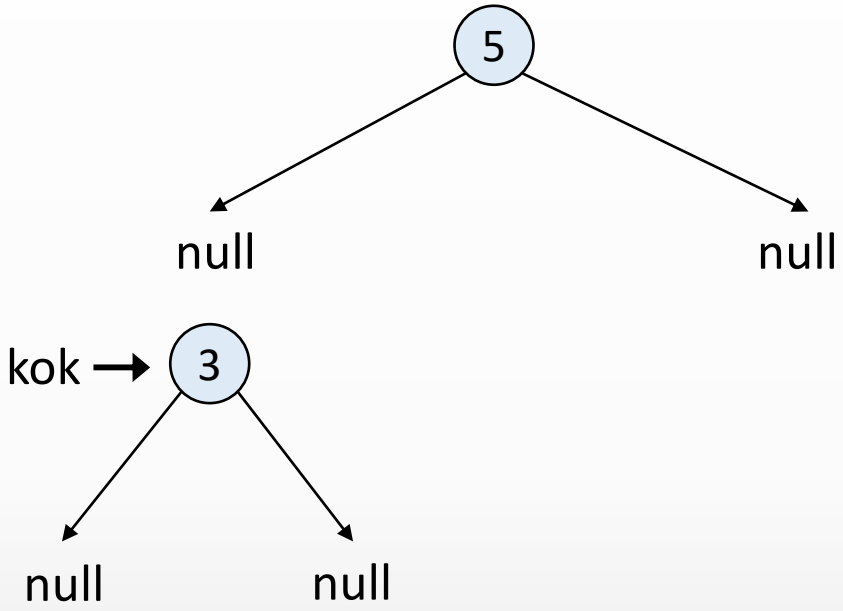

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3
ekle		3	null	null	3

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deger = 3
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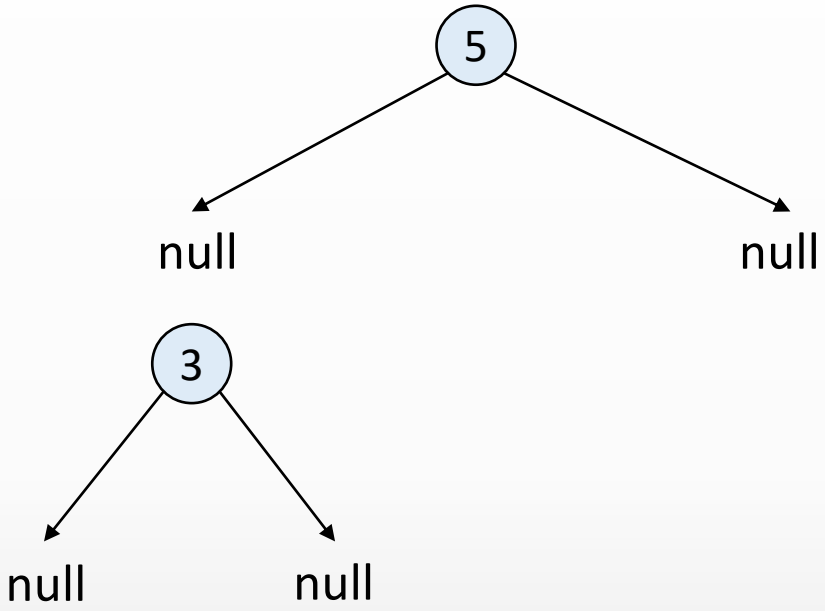

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	null	null	3

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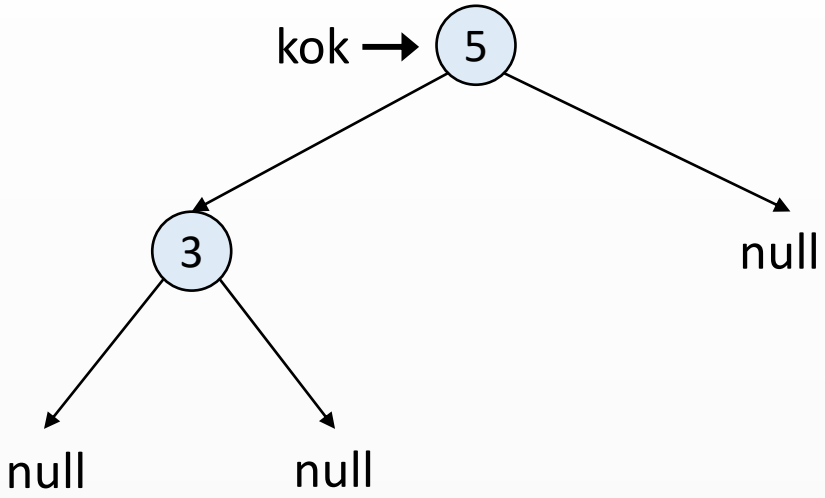

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	null	3

```
deger = 3
```

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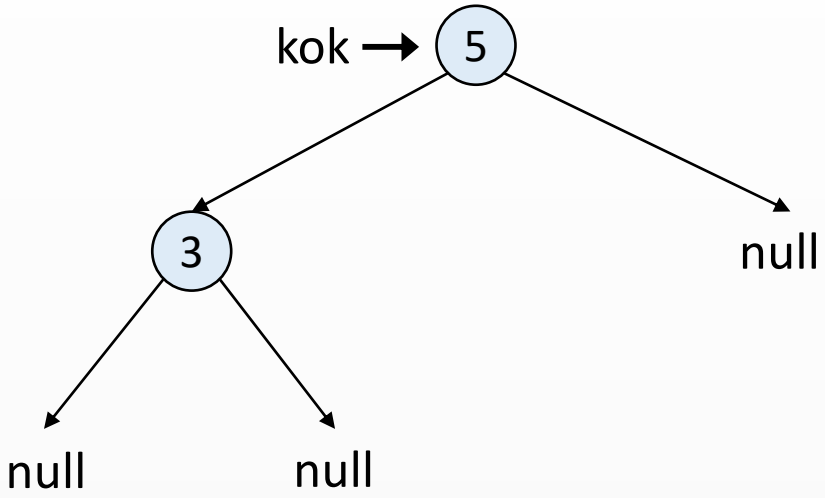

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	null	3

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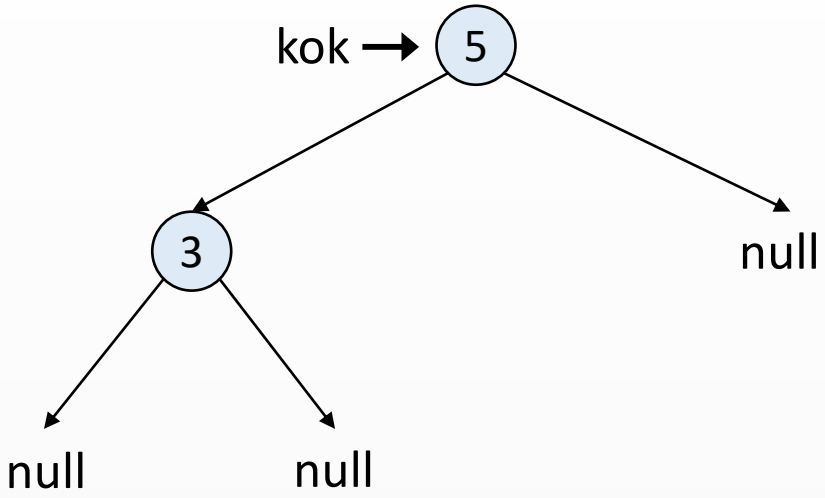

metot çağrımı	satır no	kok	sol	sag	deger

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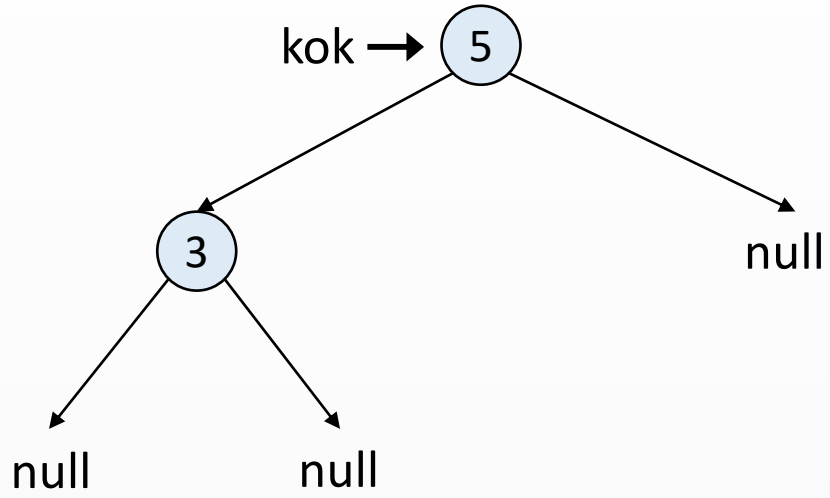

metot çağrımı	satır no	kok	sol	sag	deger

```
deger = 7
```

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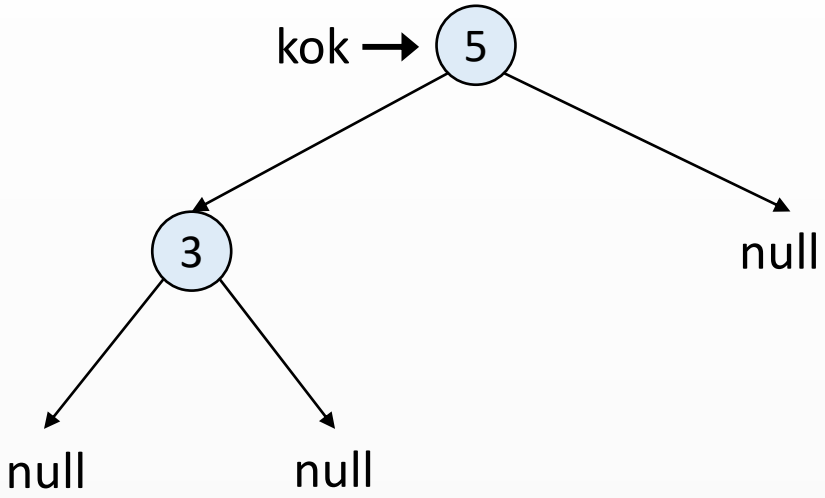

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

```
deger = 7
```

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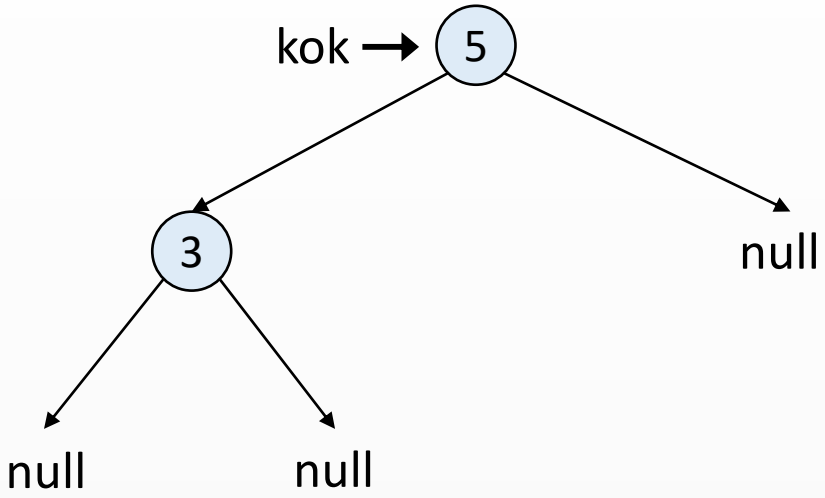

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

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deger = 7
```

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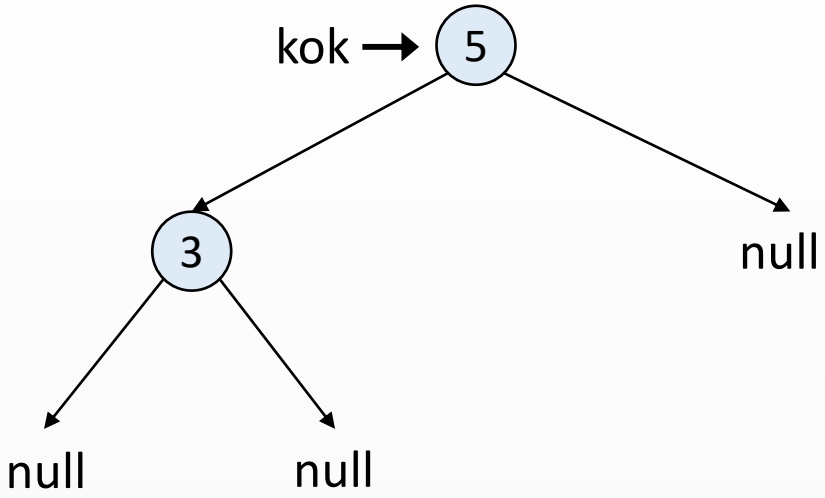

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

```
deger = 7
```

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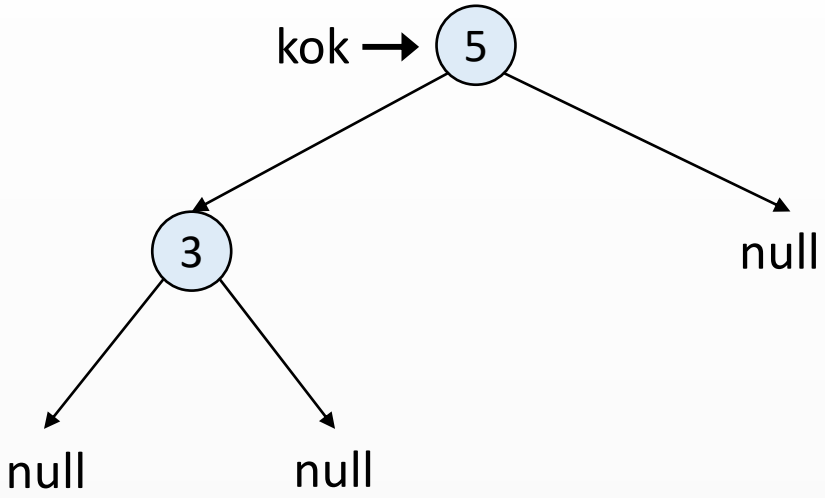

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	null	7

deger = 7

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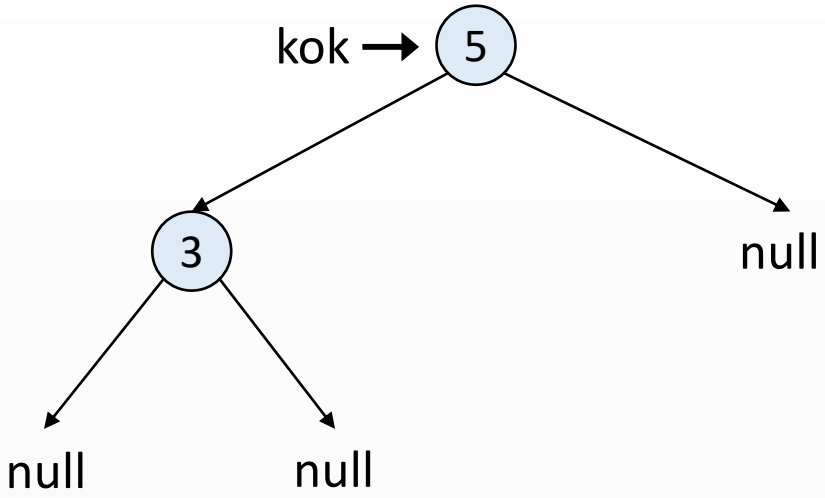

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7

deger = 7

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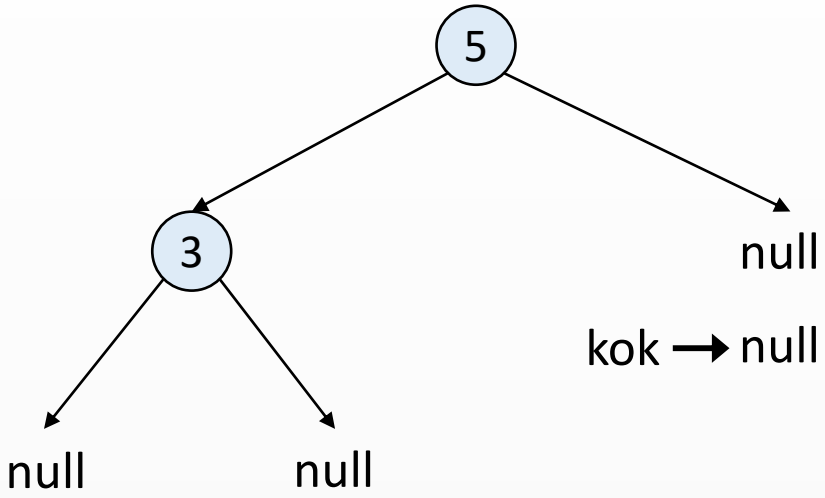

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		null	null	null	7

```
deger = 7
```

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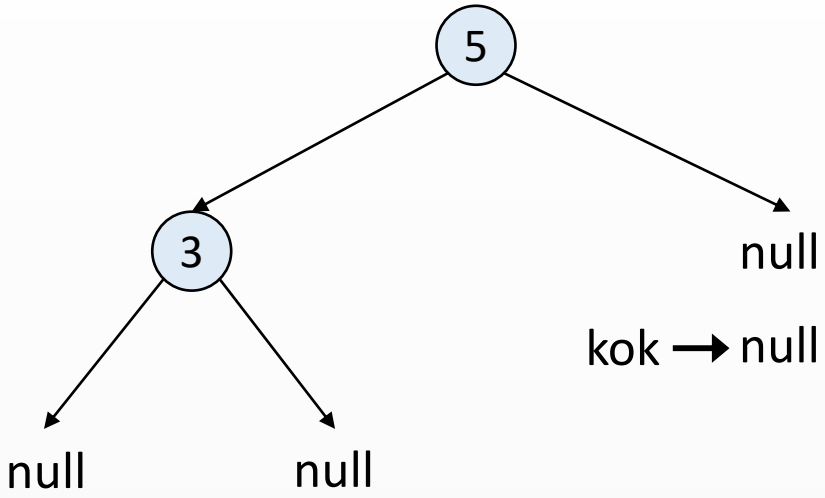

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		null	null	null	7

```
deger = 7
```

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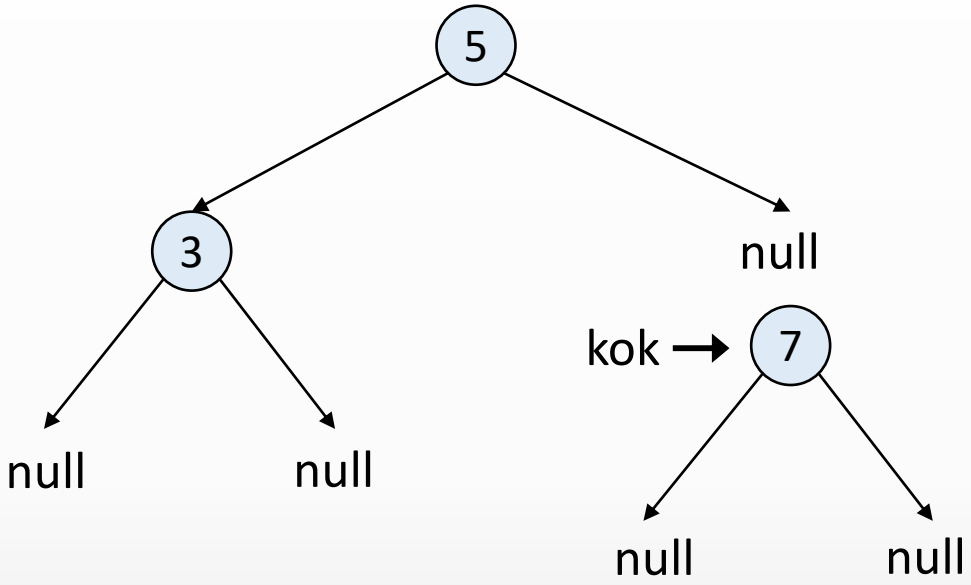

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		7	null	null	7

```
deger = 7
```

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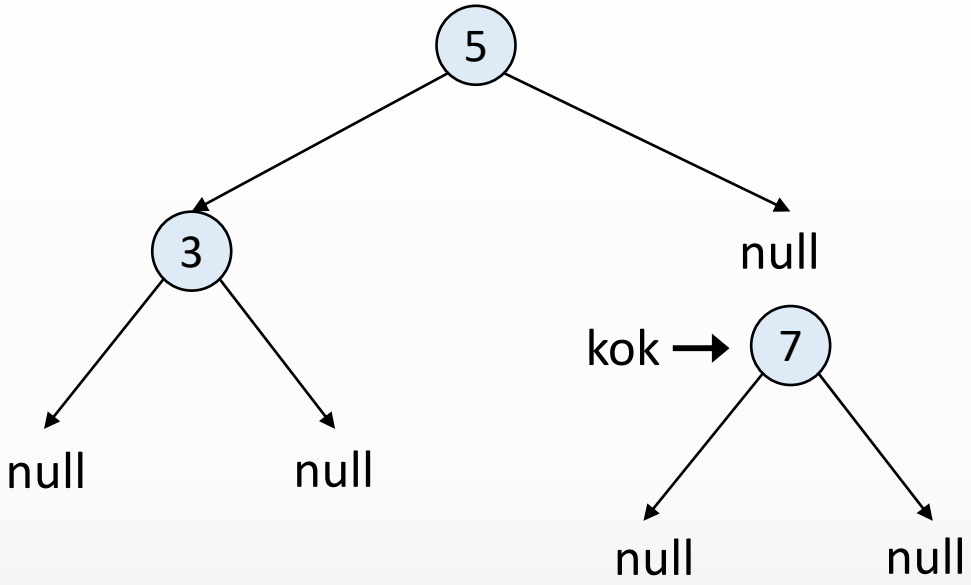

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7
ekle		7	null	null	7

deger = 7

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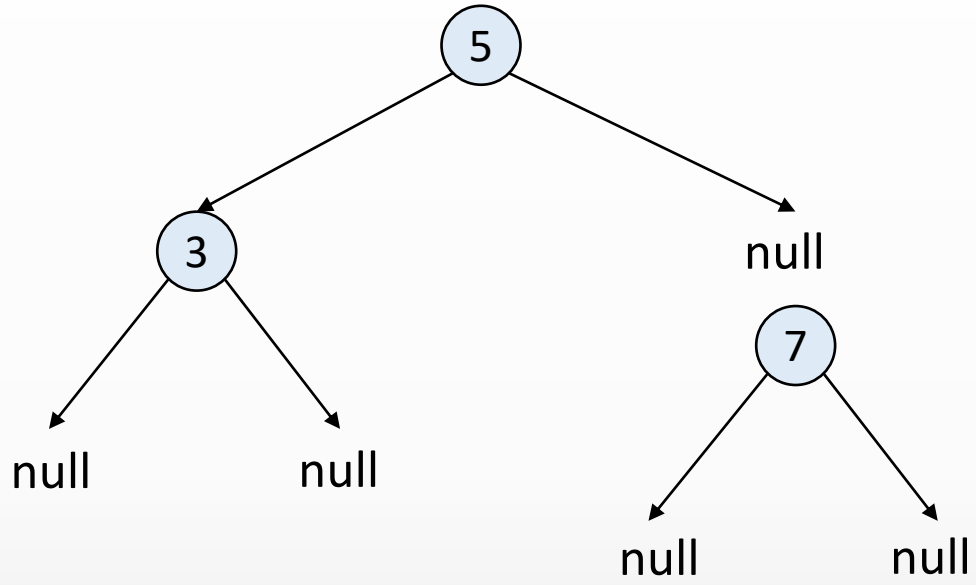

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	null	7

deger = 7

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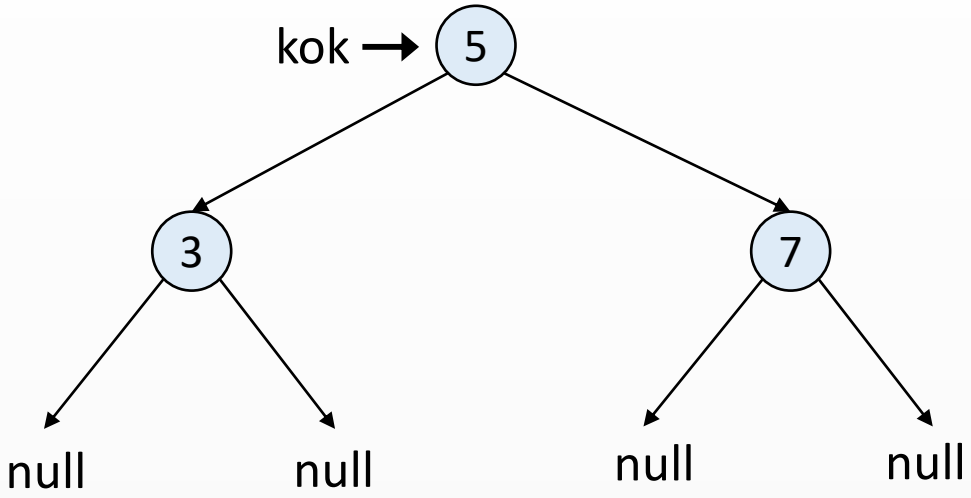

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	7	7

deger = 7

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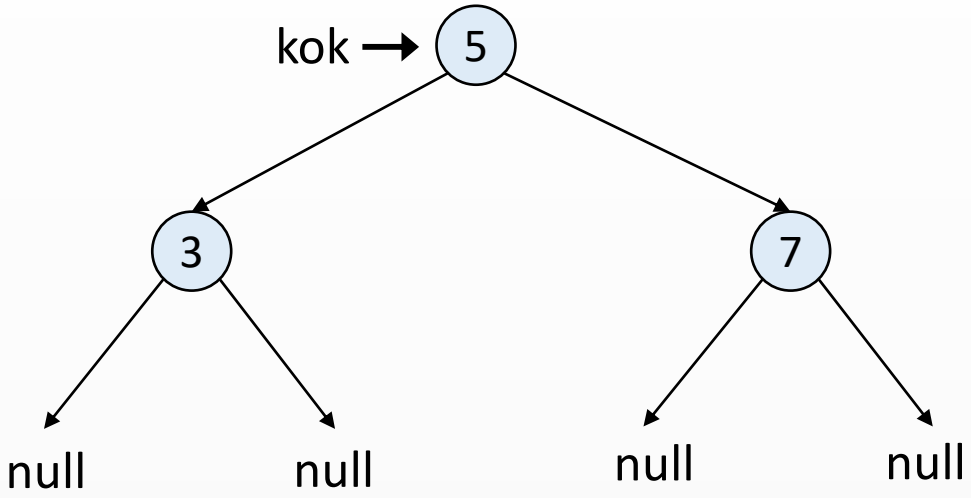

metot çağrımı	satır no	kok	sol	sag	deger
ekle	10	5	3	7	7

```
deger = 7
```

```
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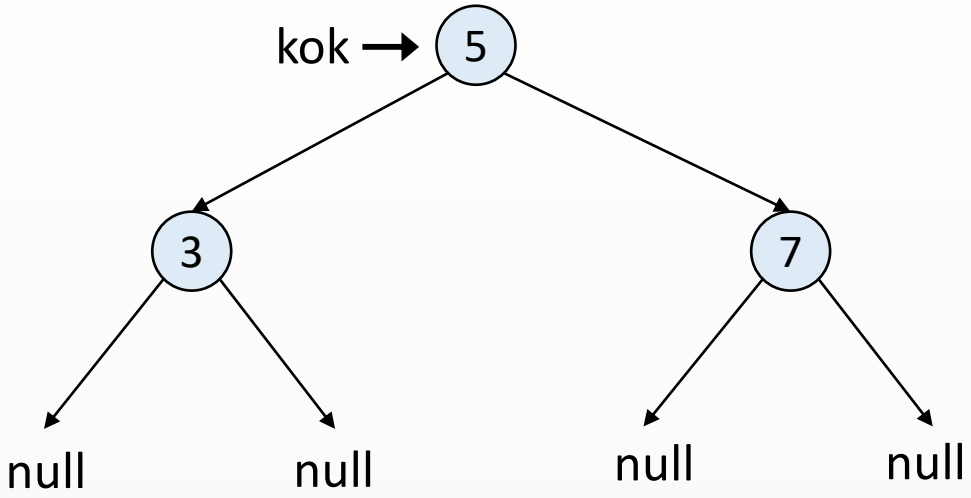

metot çağrımı	satır no	kok	sol	sag	deger

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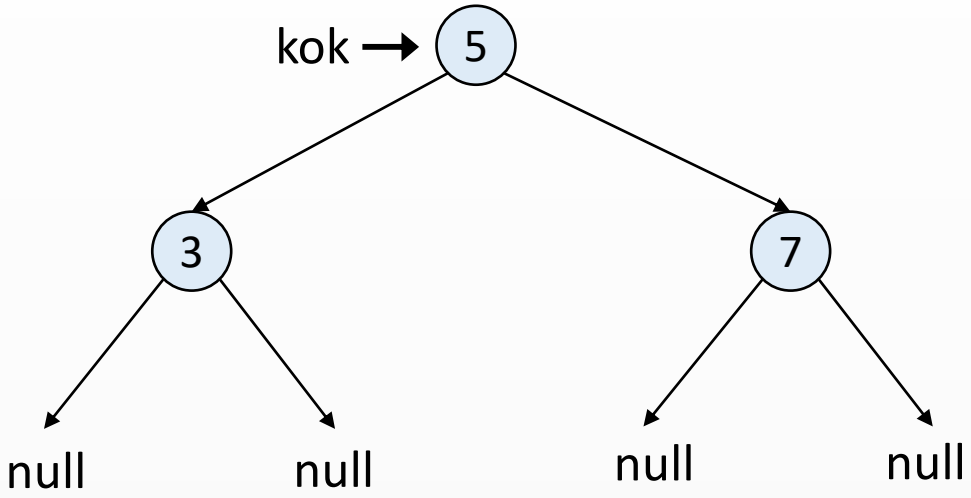

metot çağrımı	satır no	kok	sol	sag	deger

```
deger = 1
```

```
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 2 {
 3   if(kok == null) {
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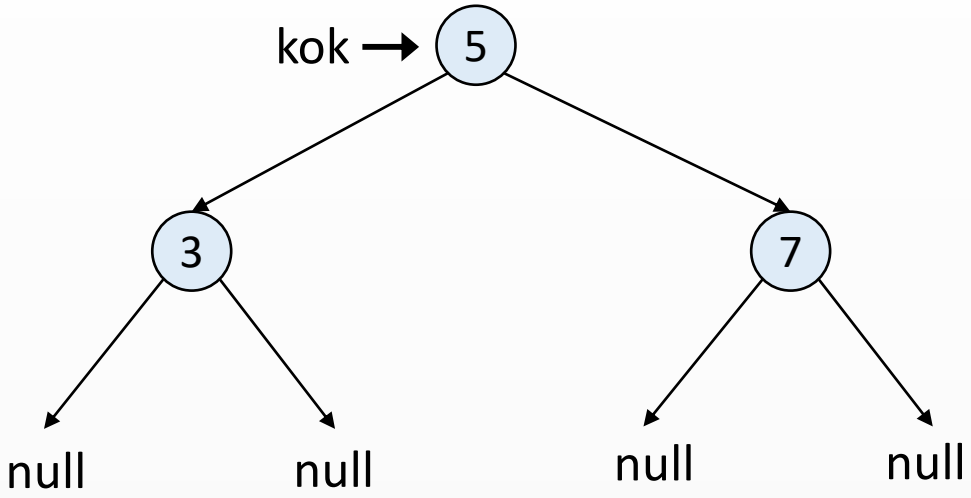

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	7	1

```
deger = 1
```

```
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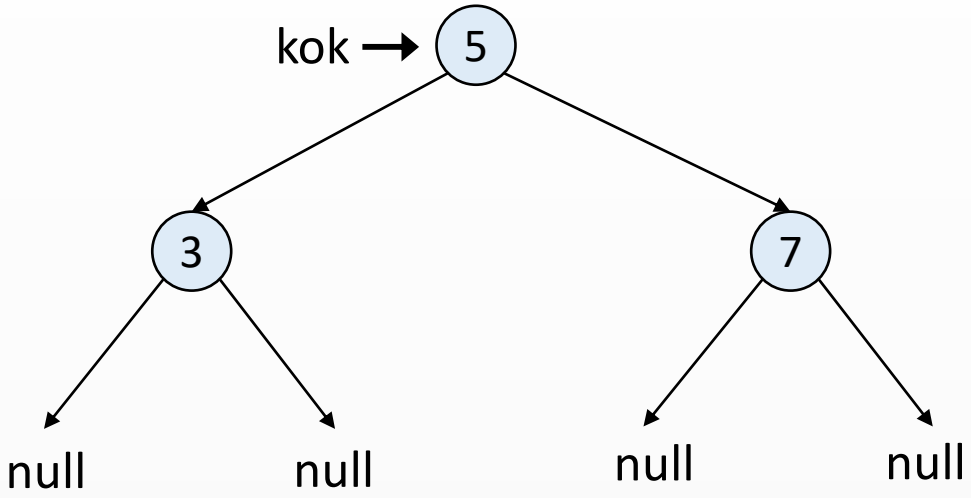

metot çağrımı	satır no	kok	sol	sag	deger
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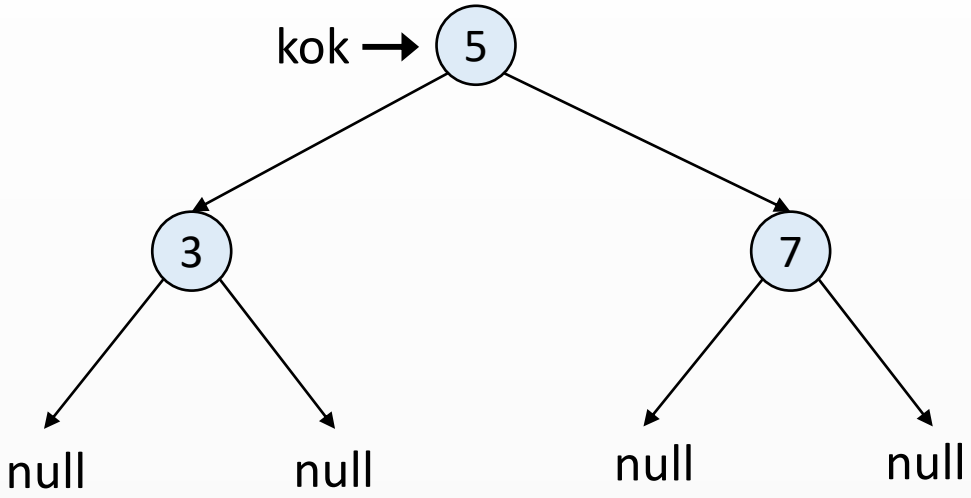

metot çağrımı	satır no	kok	sol	sag	deger
ekle		5	3	7	1

```
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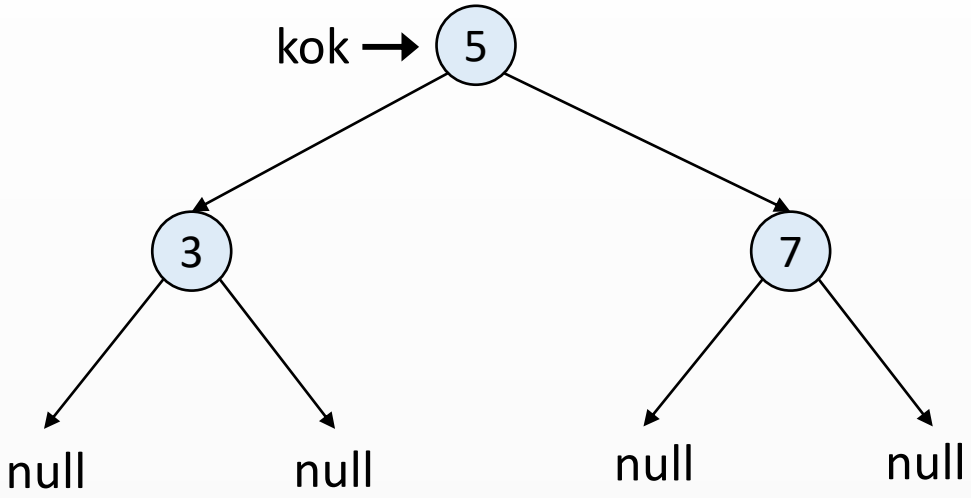

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1

```
deger = 1
```

```
 1 public AgacDugumu ekle(AgacDugumu kok, int deger)
 2 {
 3   if(kok == null) {
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 6   }
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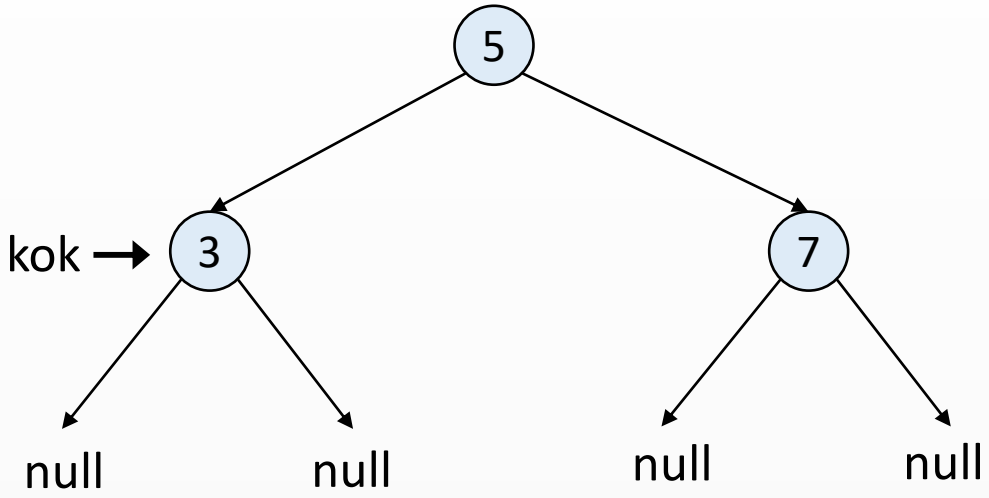

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1

```
deger = 1
```

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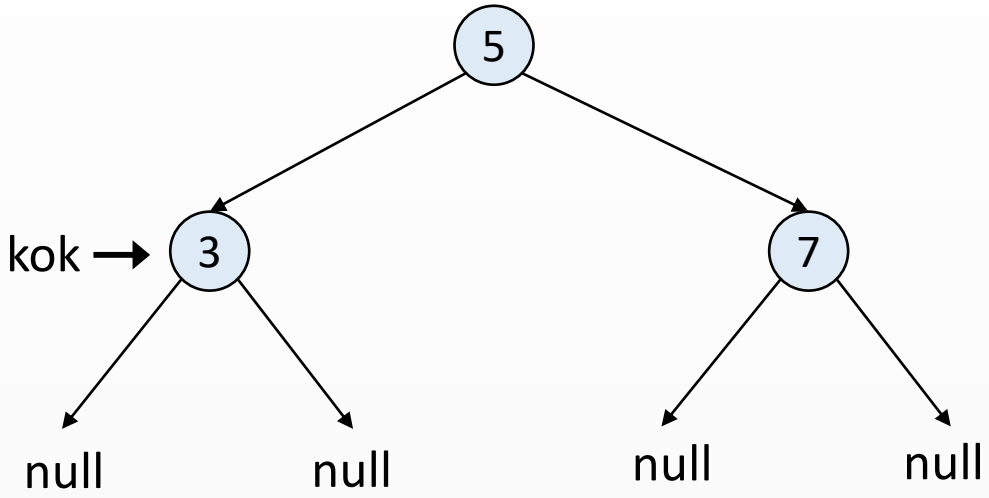

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1

```
deger = 1
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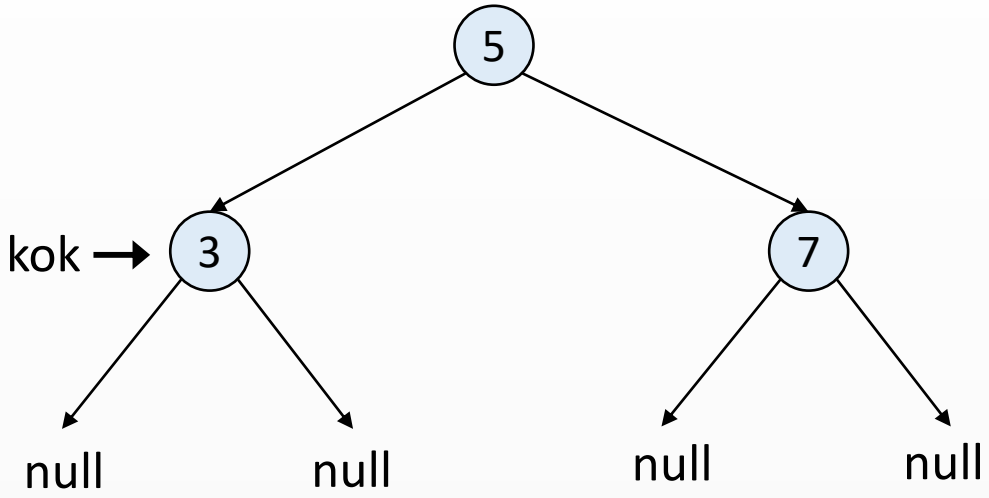

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle		3	null	null	1

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deger = 1
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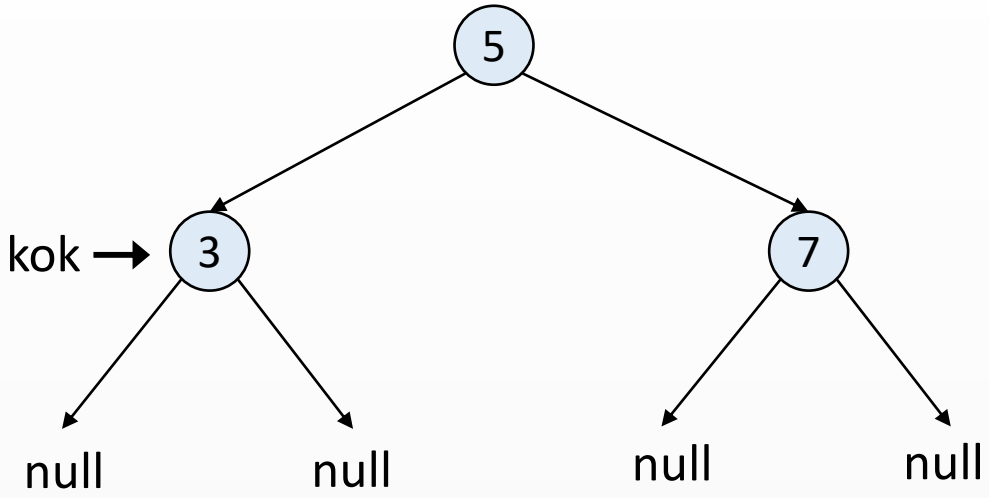

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1
ekle	8	3	null	null	1

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deger = 1
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```
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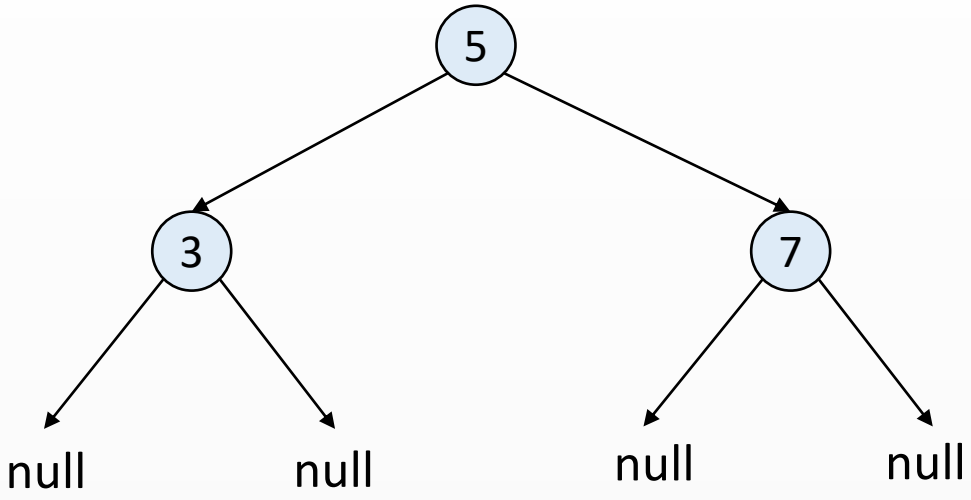

kok → null

deger = 1

metot çağrımı	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) {
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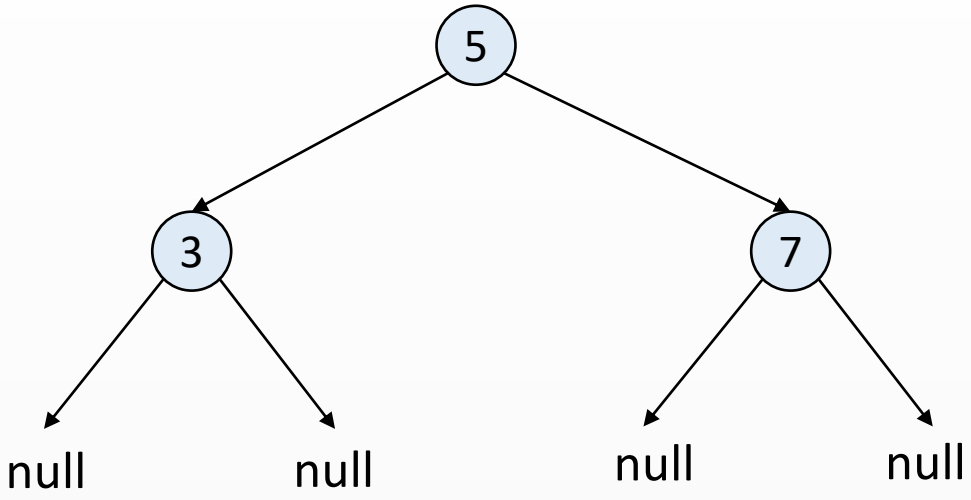

kok → null

deger = 1

metot çağrımı	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)
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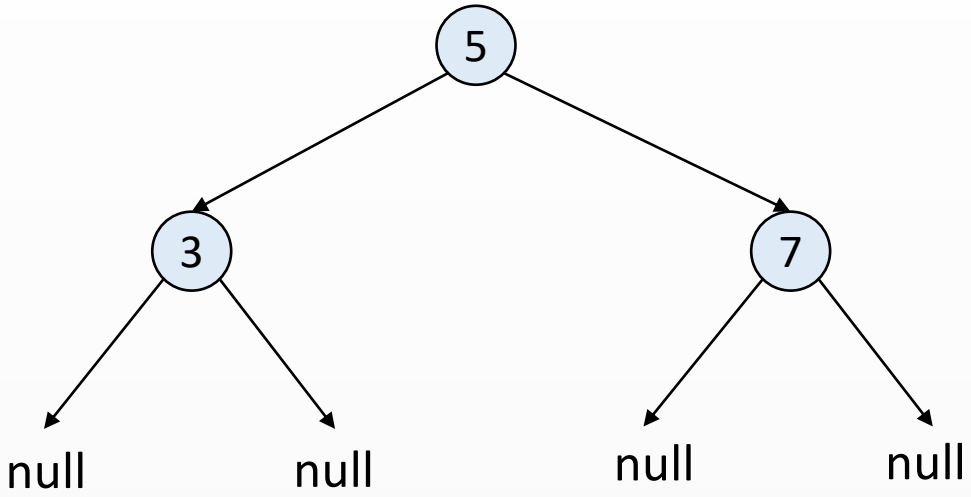

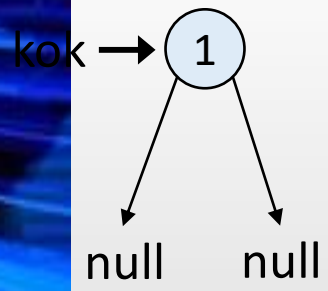

deger = 1

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

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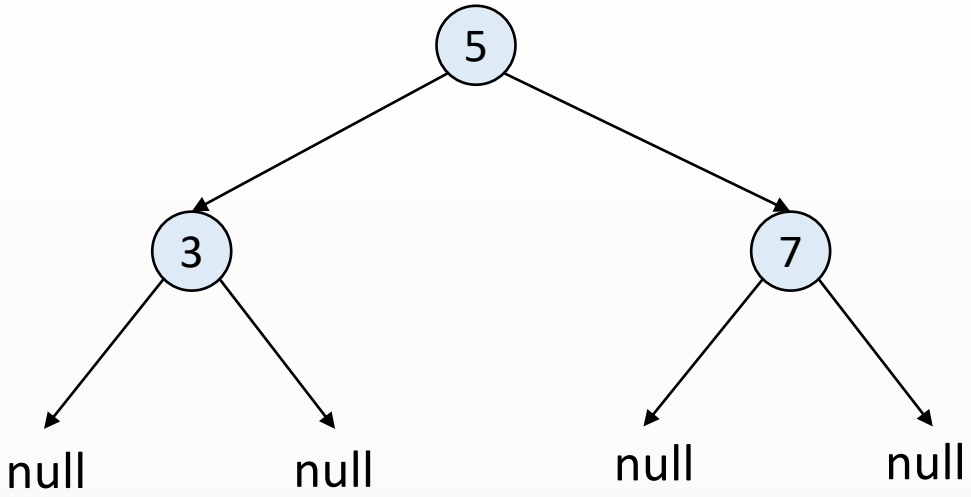

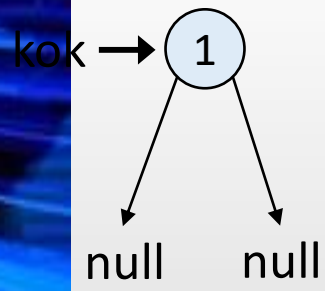

deger = 1

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

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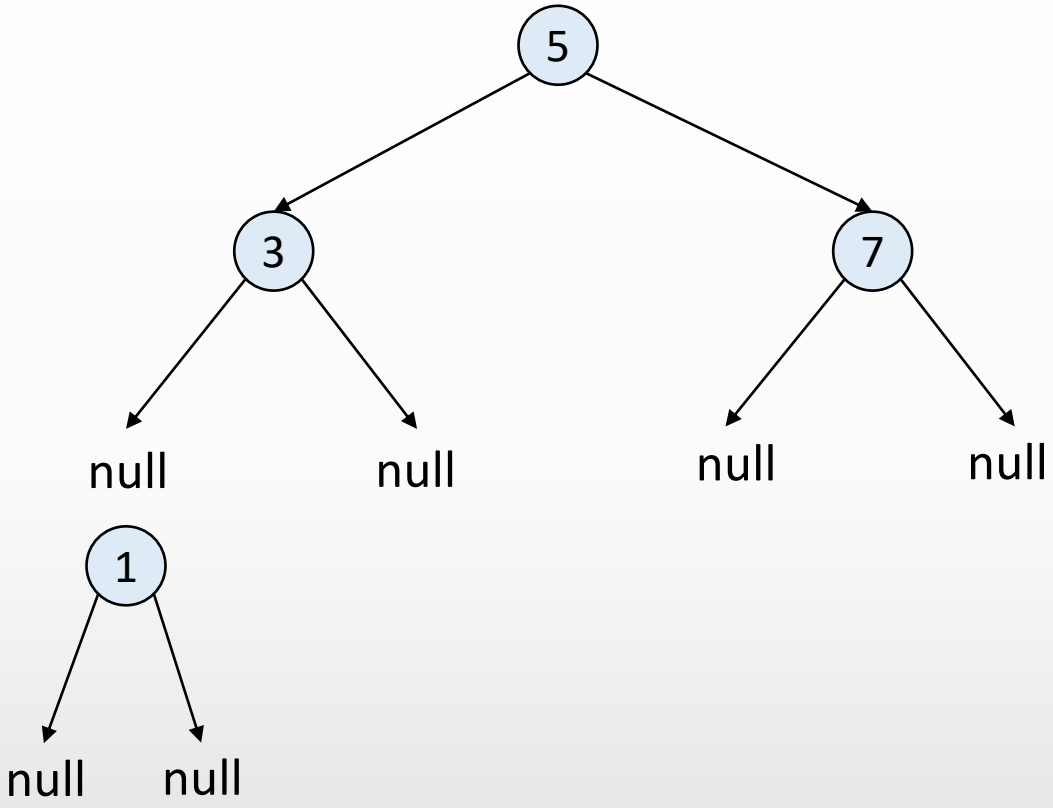
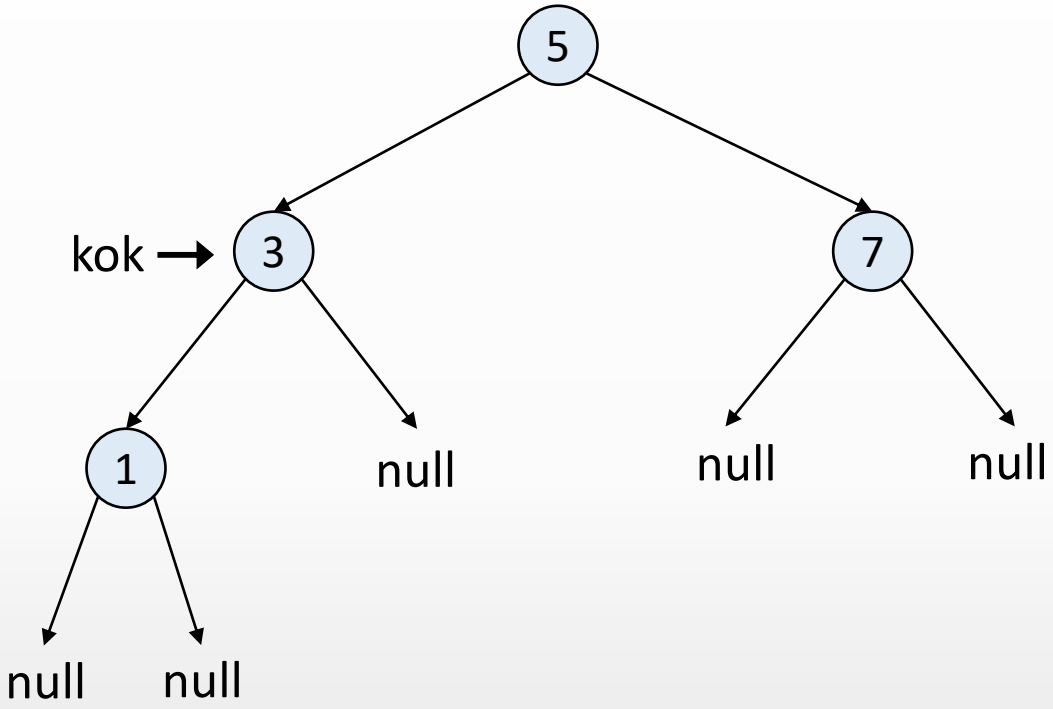
 7   if(deger < kok.veri)
 8     kok.sol = ekle(kok.sol, deger);
 9   else
10     kok.sag = ekle(kok.sag, deger);
11   return kok;
12 }
```



deger = 1

metot çağrımı	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) {
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 }
```



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

```
deger = 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 }
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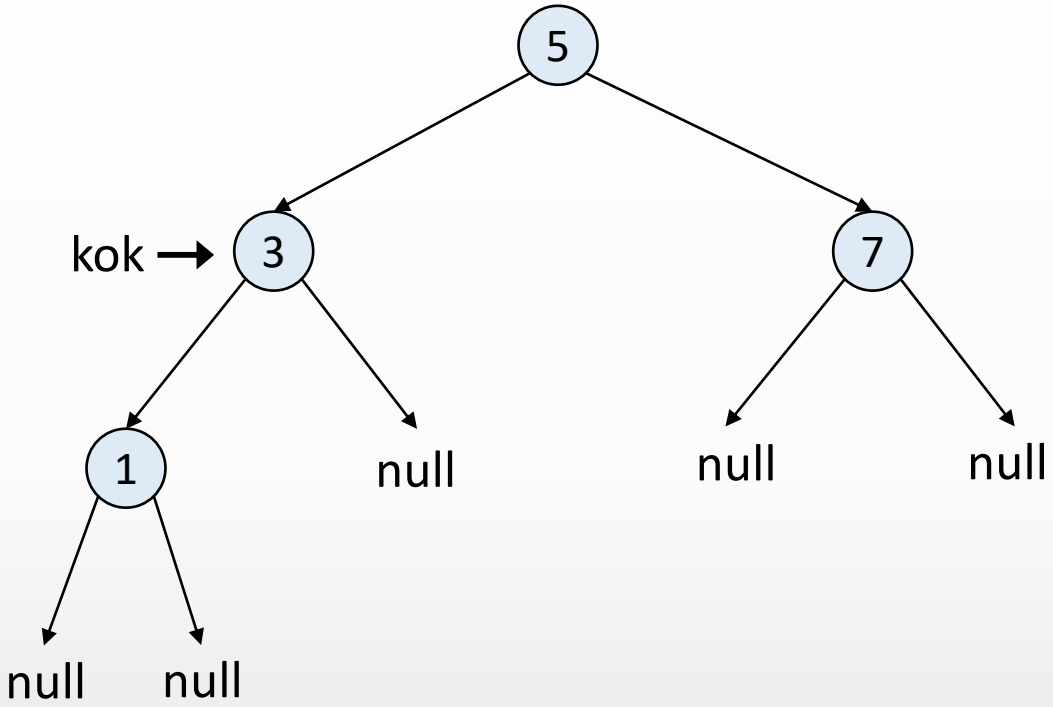

deger = 1

metot çağrımı	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)
 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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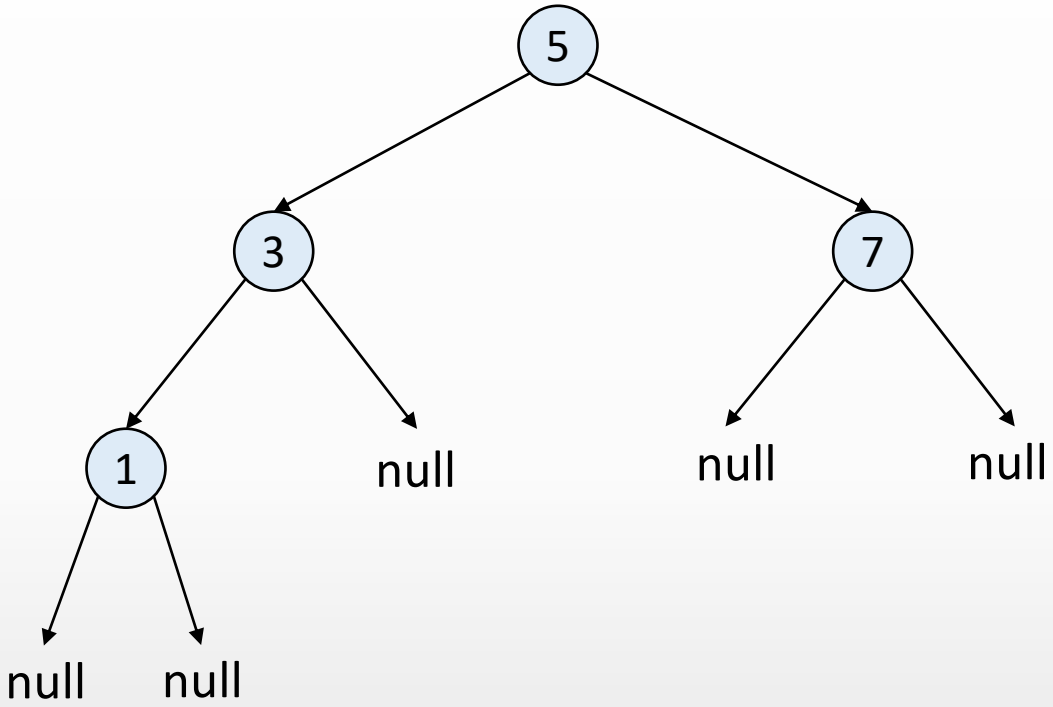

metot çağrımı	satır no	kok	sol	sag	deger
ekle	8	5	3	7	1

```
deger = 1
```

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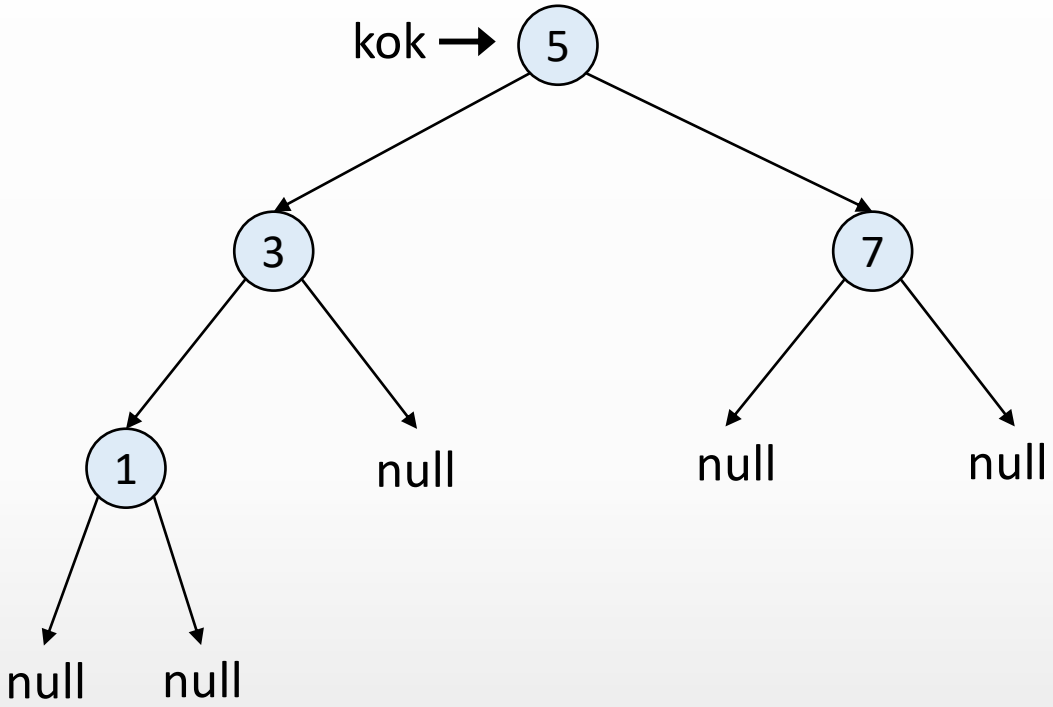

deger = 1

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

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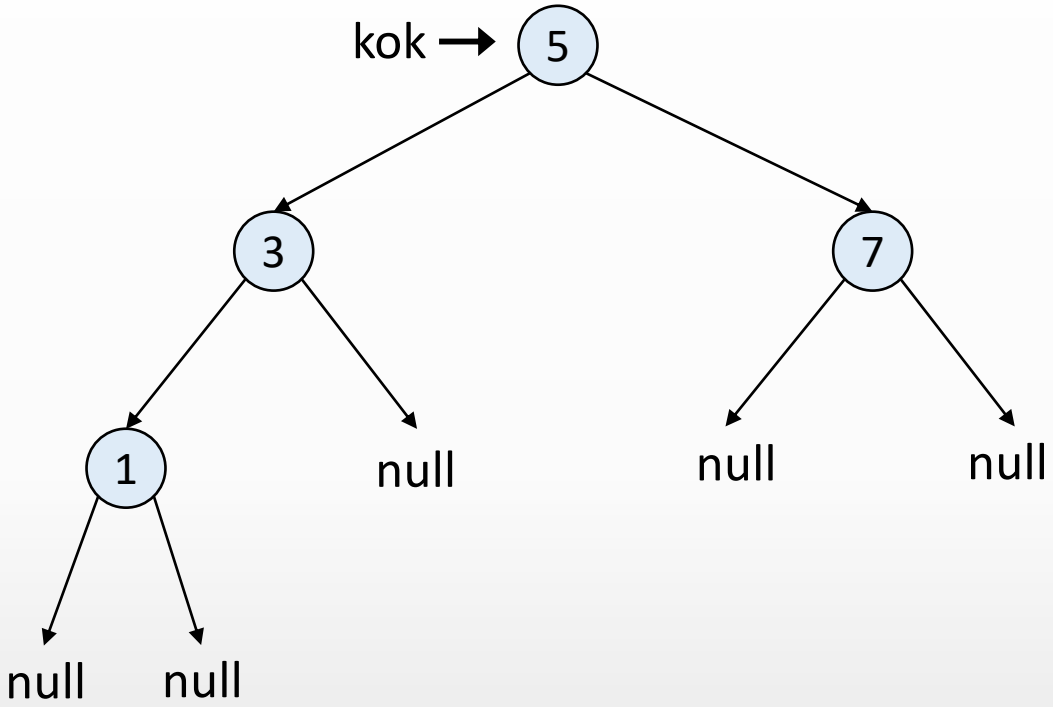

deger = 1

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

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 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 }
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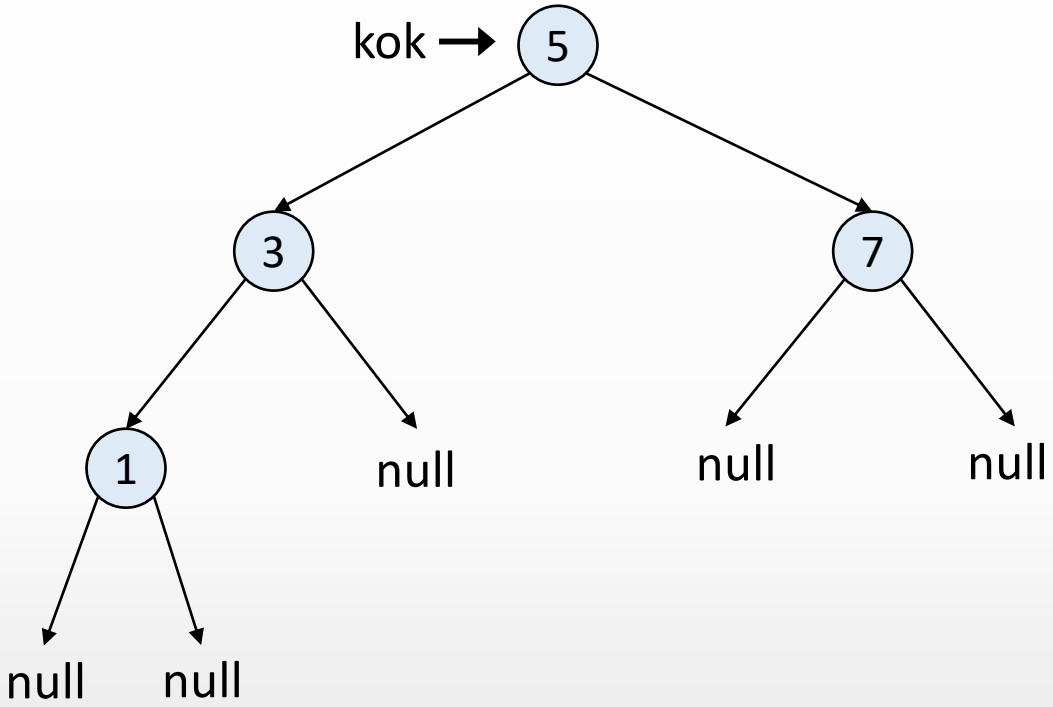

metot çağrımı	satır no	kok	sol	sag	deger

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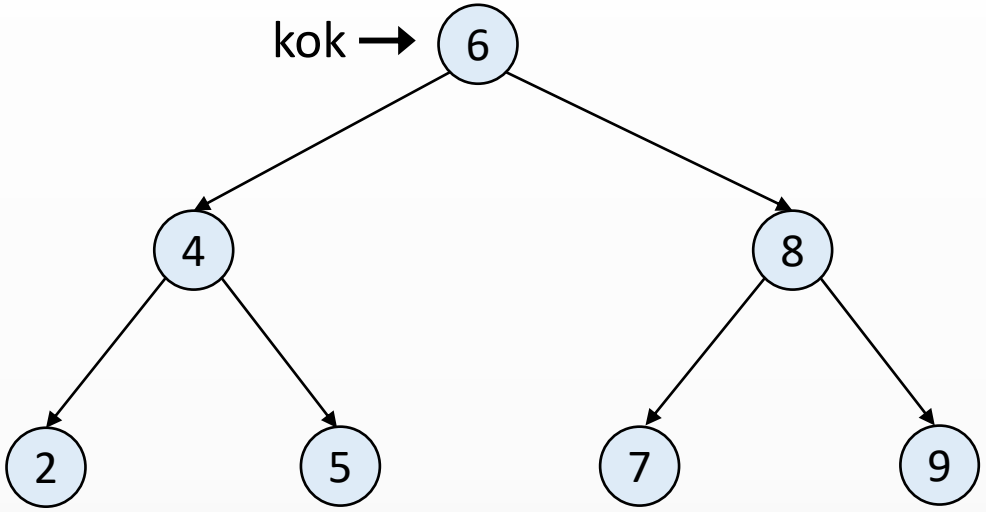
8     kok.sol = ekle(kok.sol, deger);
9   else
10    kok.sag = ekle(kok.sag, deger);
11  return kok;
12 }
```

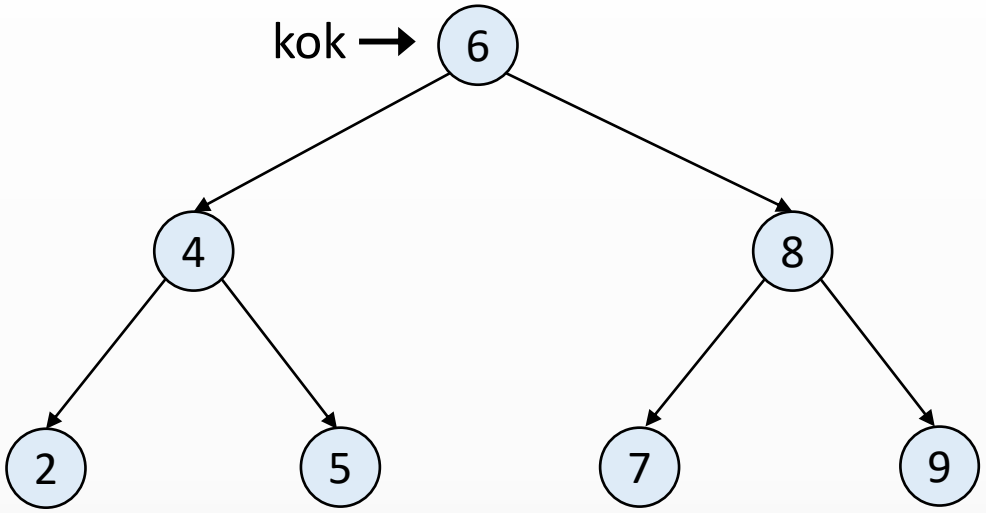
Verilen Bir Anahtarı İkili Arama Ağacında Arama

metot çağrımı	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 }
```

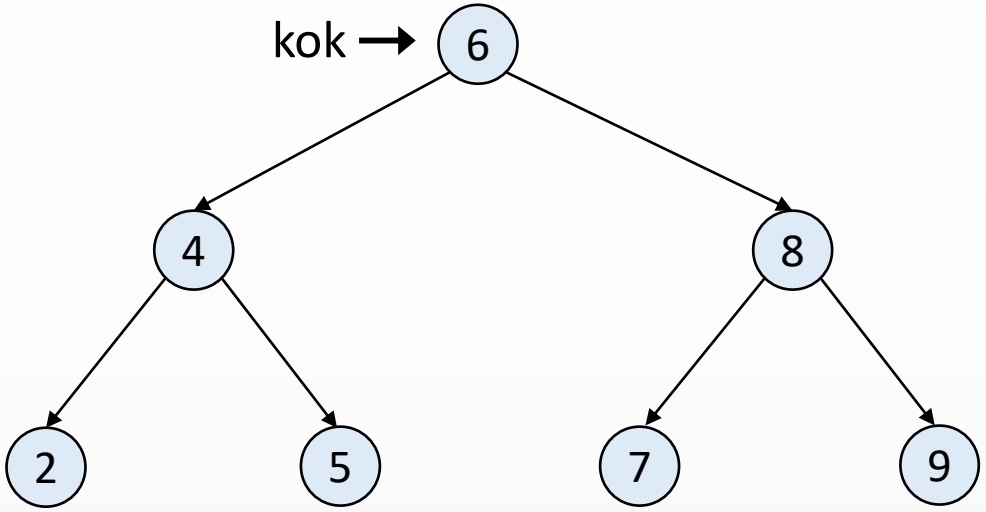
metot çağrımı	satır no	kok	anahtar



anahtar = 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 }
```

metot çağrımı	satır no	kok	anahtar
ara		6	5



anahtar = 5

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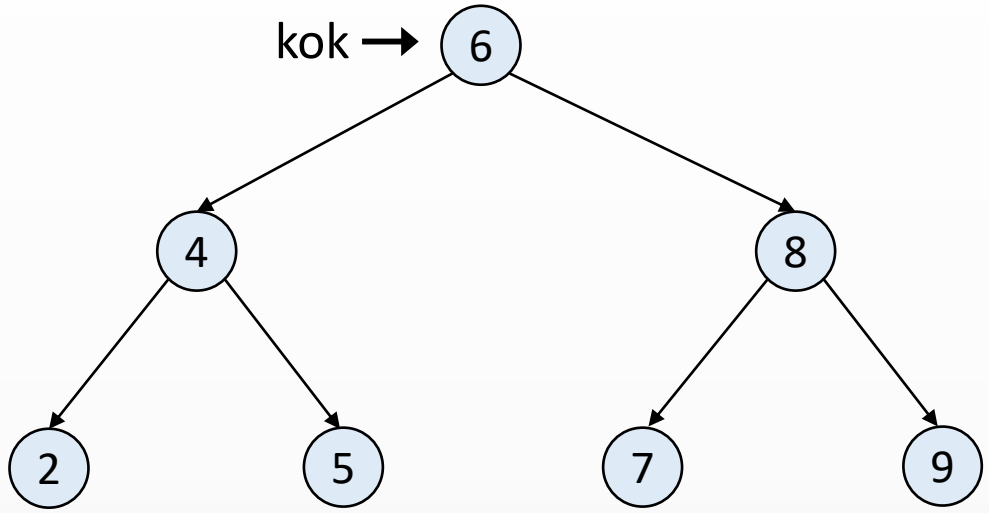
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	satır no	kok	anahtar
ara		6	5

```
anahtar = 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
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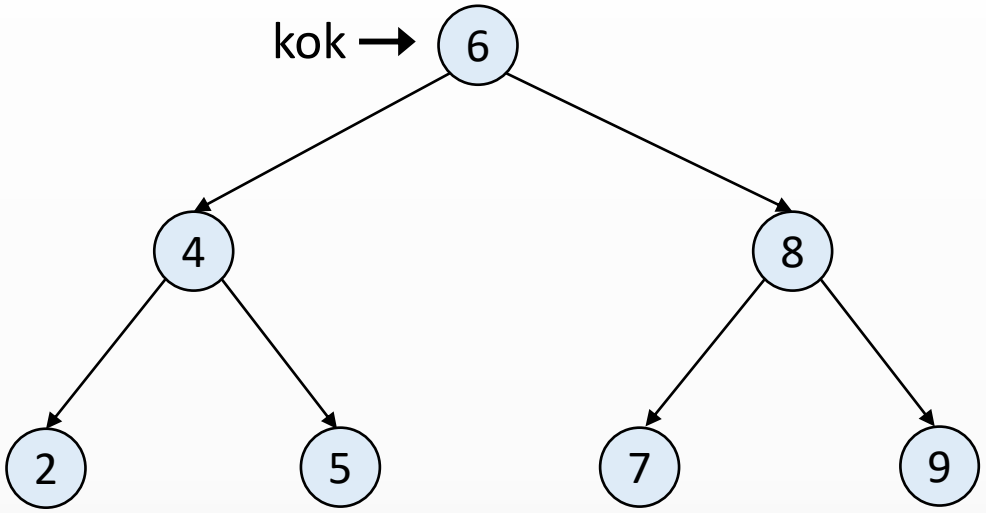
10 }
```



metot çağrımı	satır no	kok	anahtar
ara		6	5

```
anahtar = 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
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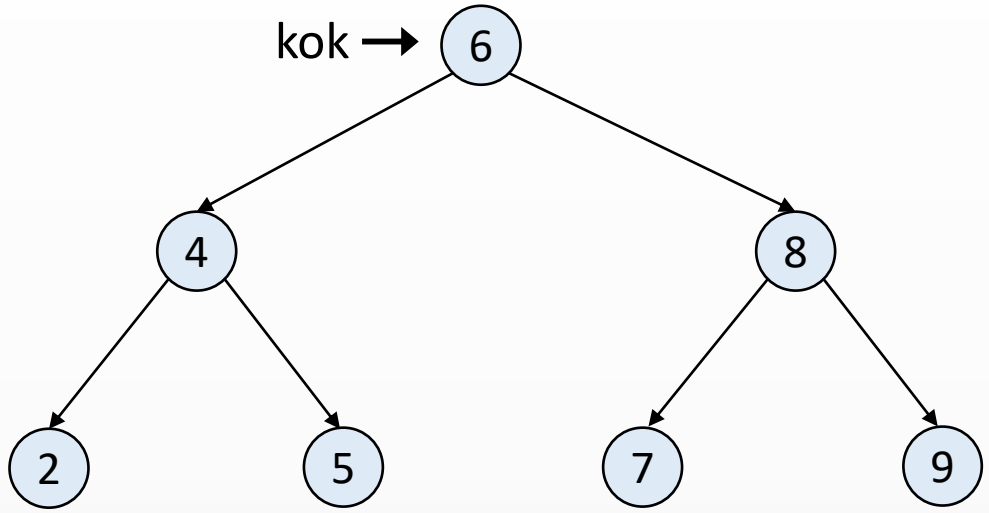
```



metot çağrımı	satır no	kok	anahtar
ara	7	6	5

anahtar = 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 }
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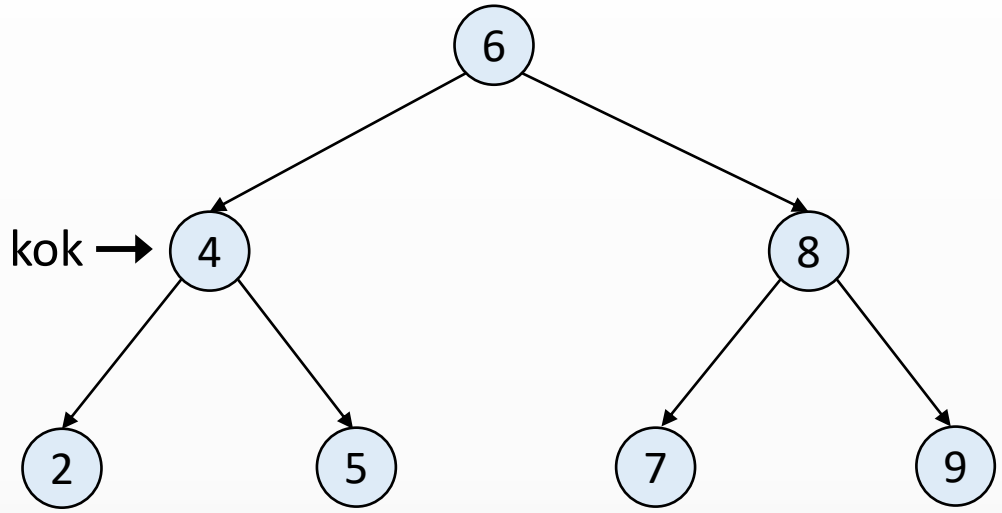
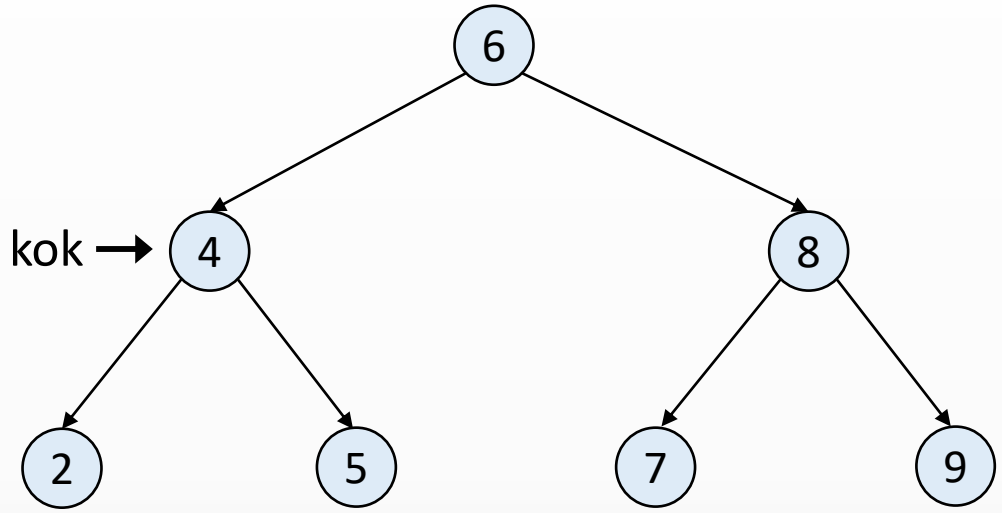


metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

```
anahtar = 5
```

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

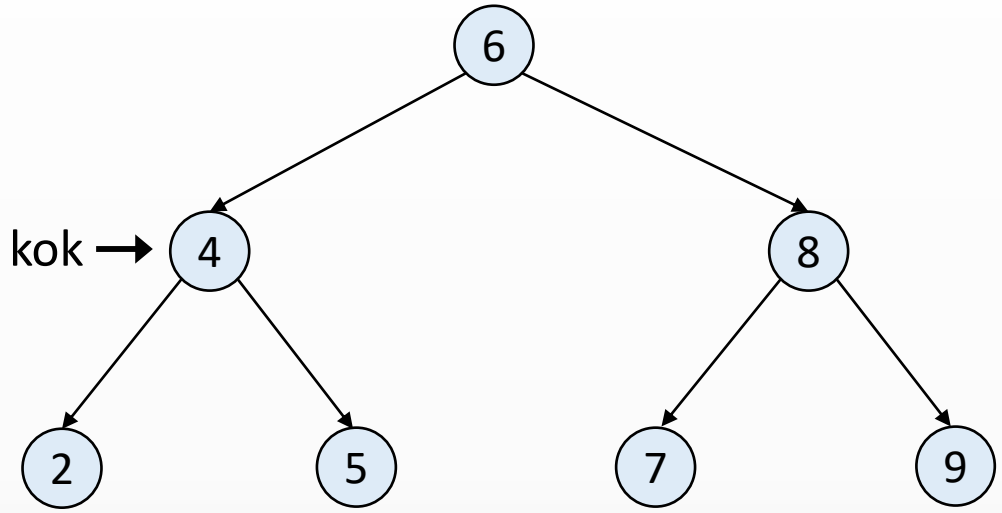

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

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
 9     return ara(kok.sag, anahtar);
10 }
```

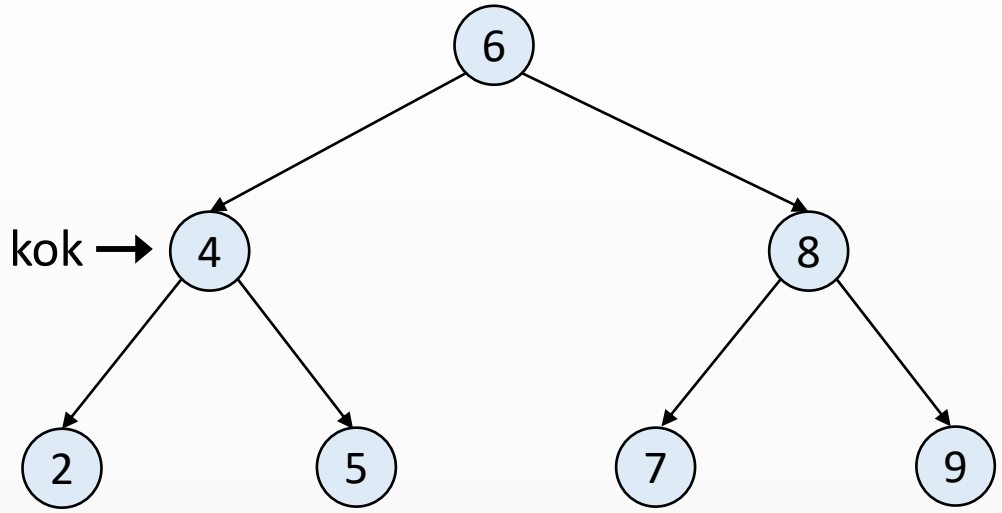

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara		4	5

anahtar = 5

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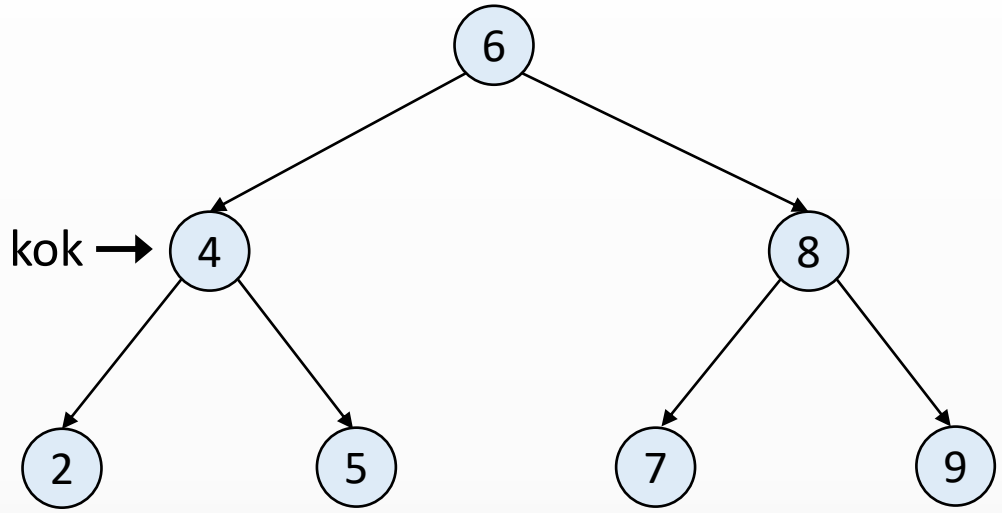
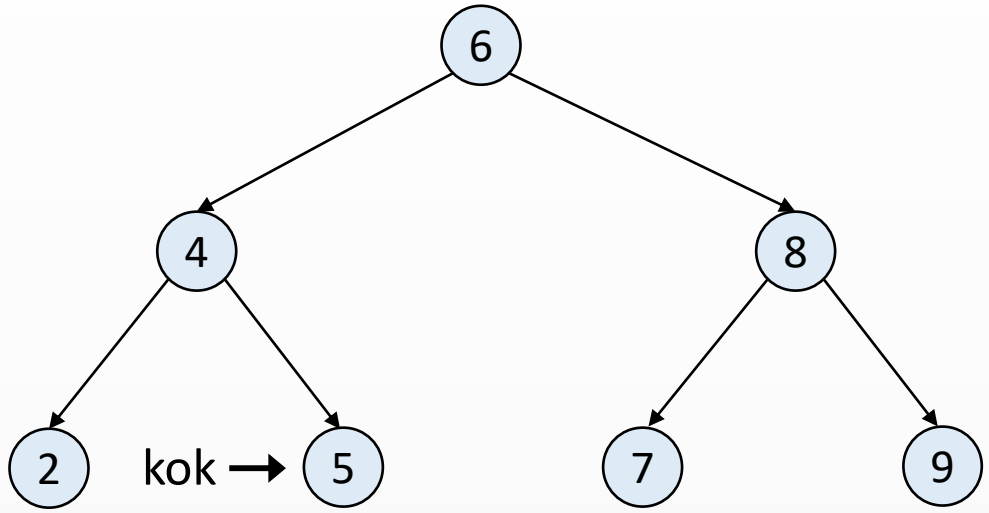


metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5

anahtar = 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 }
```



metot çağrımı	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)
 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);
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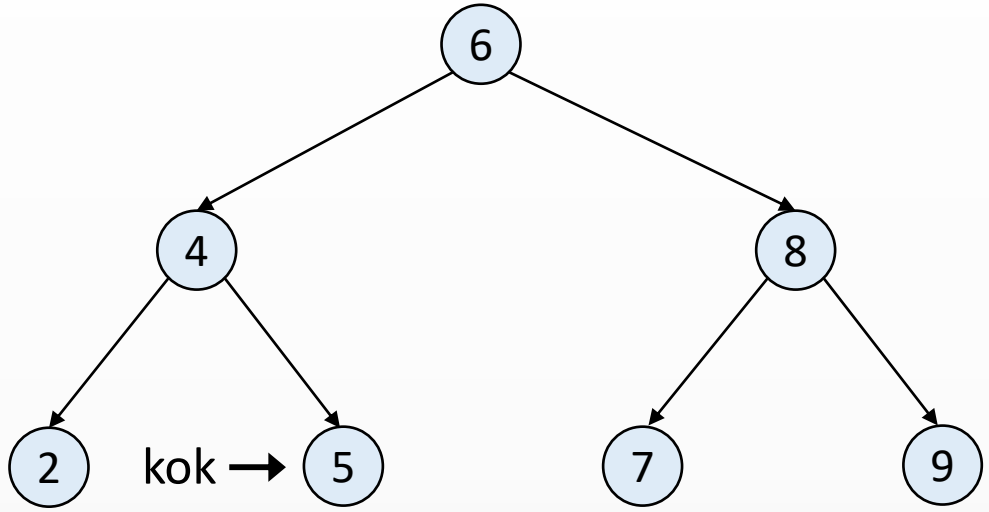

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5
ara		5	5

anahtar = 5

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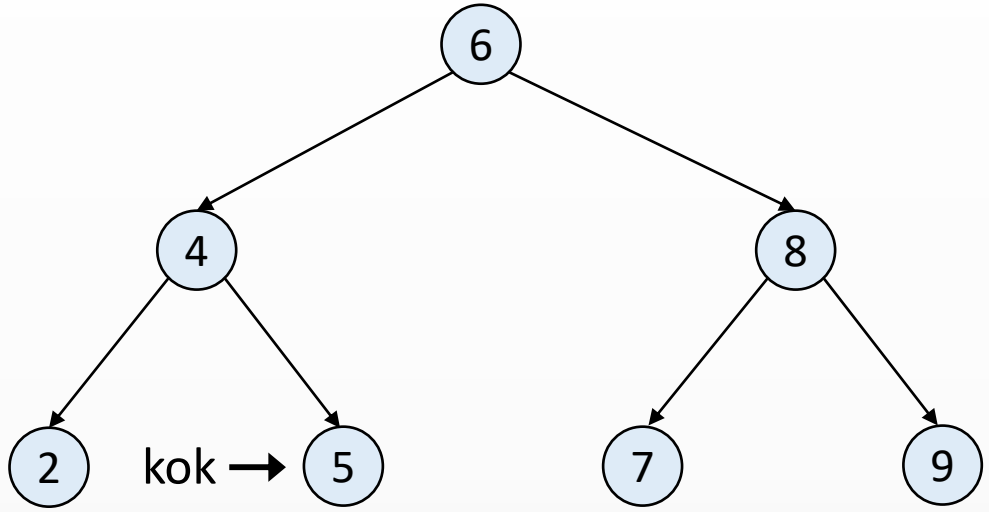

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5
ara		5	5

anahtar = 5

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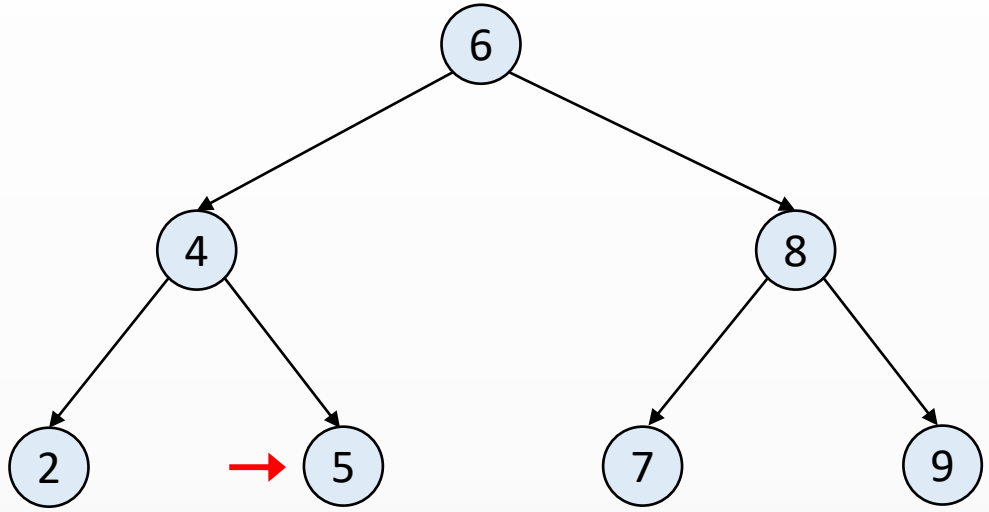

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5

anahtar = 5

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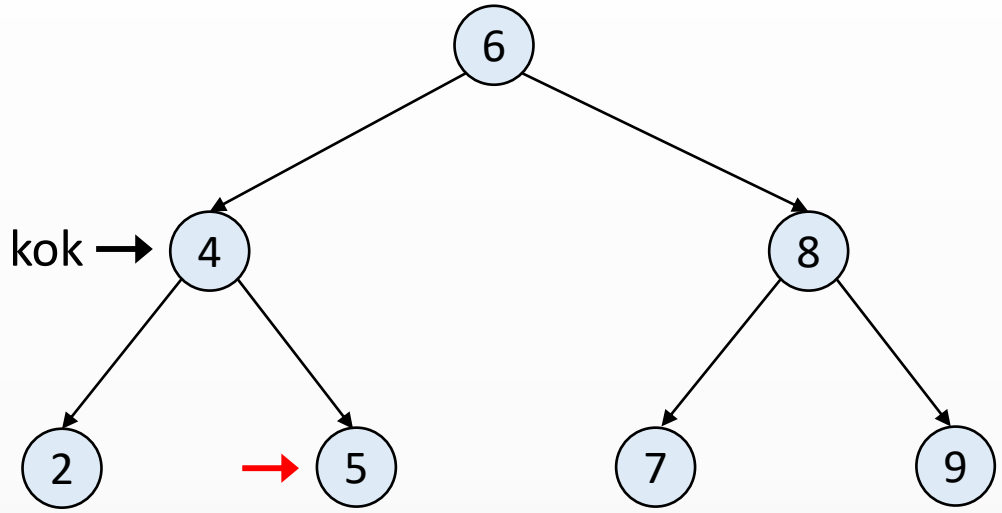

metot çağrımı	satır no	kok	anahtar
ara	7	6	5
ara	9	4	5

anahtar = 5

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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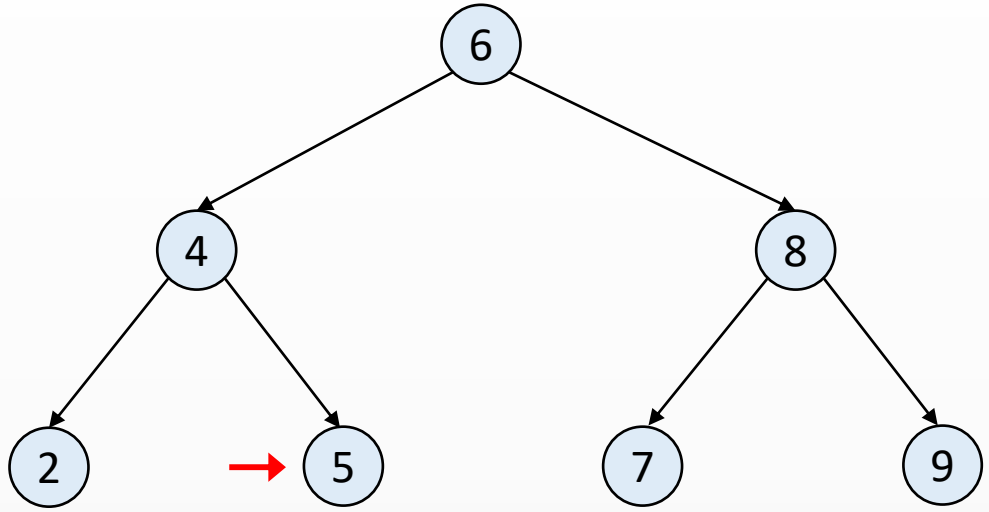

metot çağrımı	satır no	kok	anahtar
ara	7	6	5

anahtar = 5

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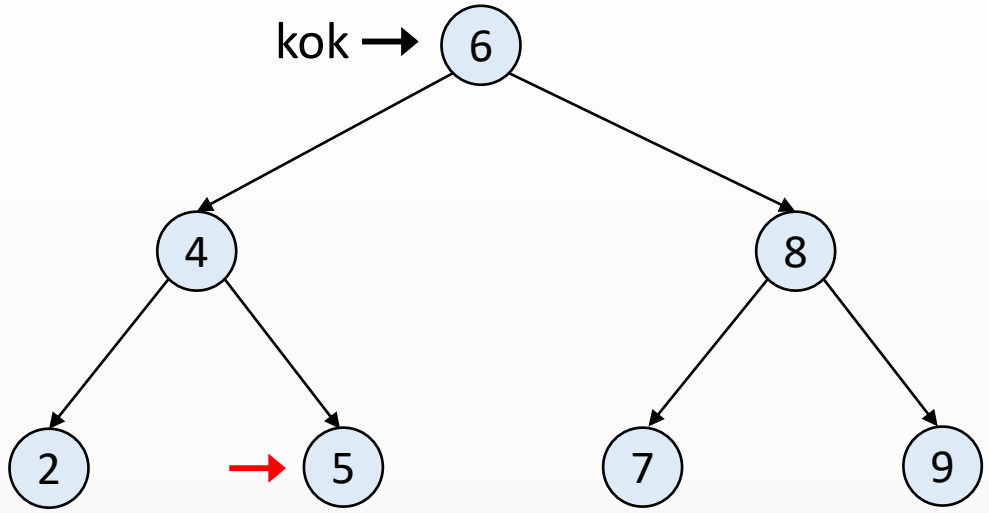

metot çağrımı	satır no	kok	anahtar
ara	7	6	5

anahtar = 5

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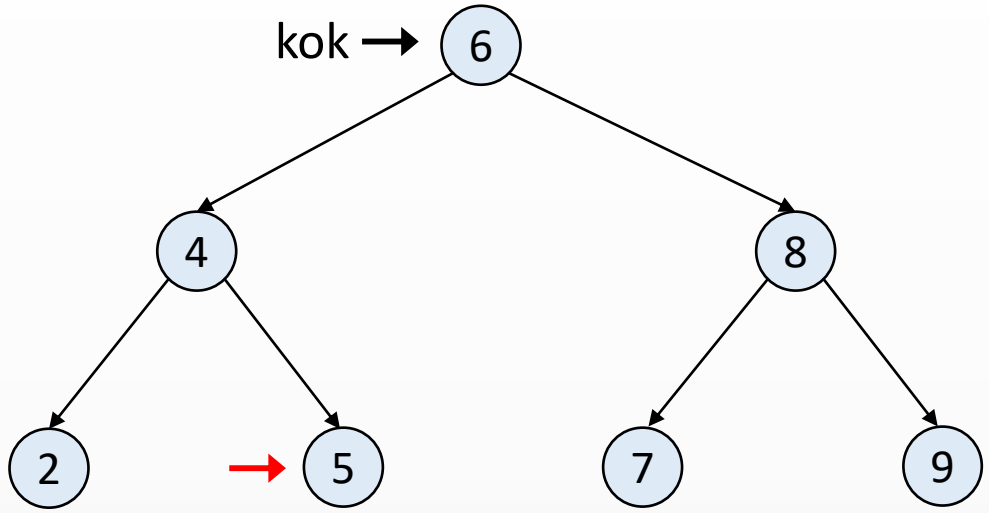

metot çağrımı	satır no	kok	anahtar

anahtar = 5

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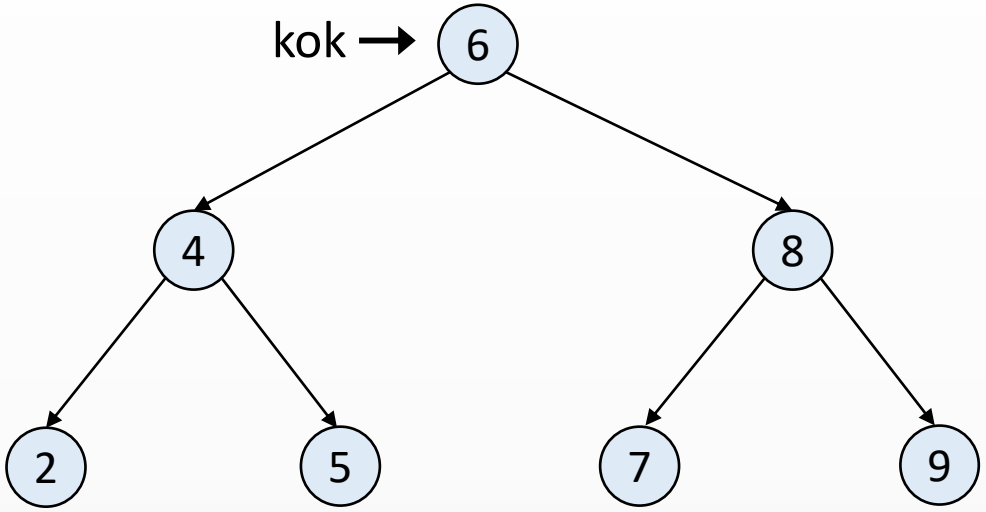

metot çağrımı	satır no	kok	anahtar

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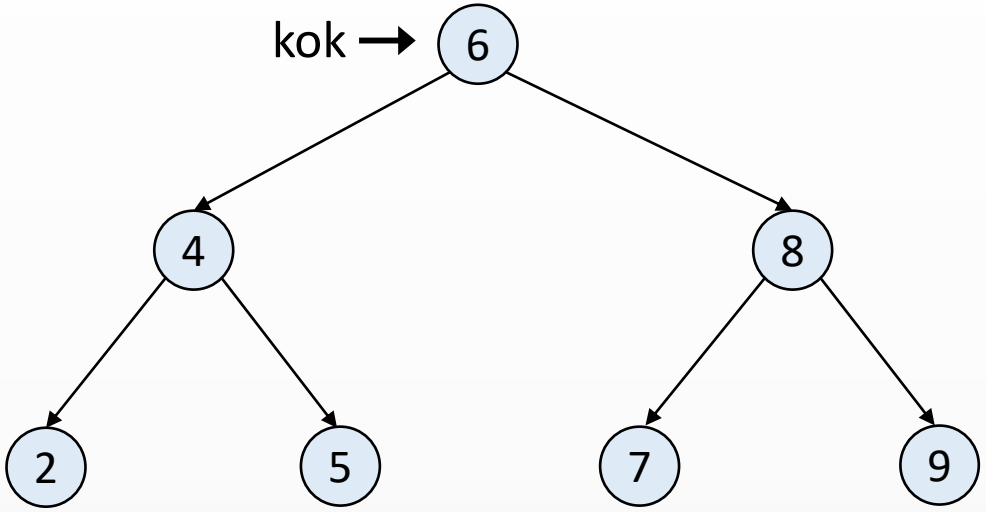
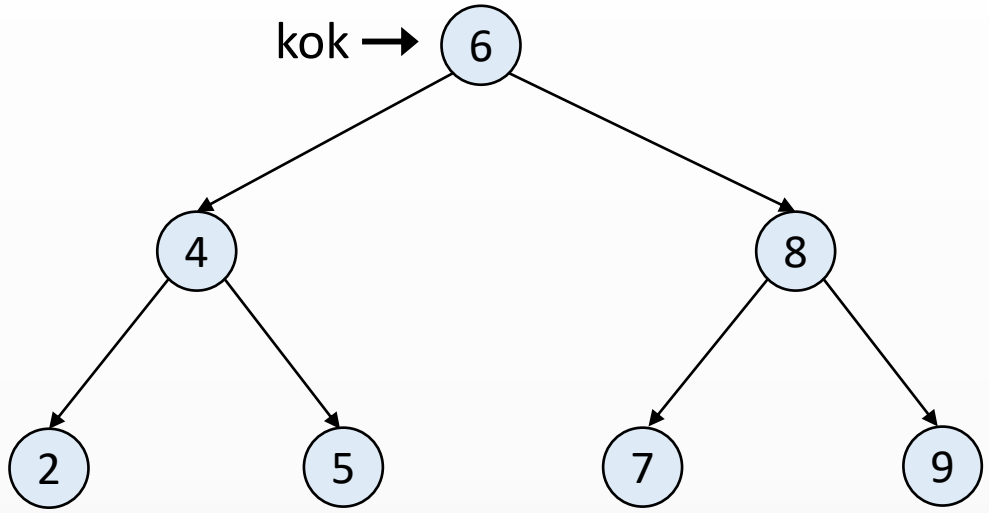
 5   }
 6   if(anahtar < kok.veri)
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	satır no	kok	anahtar

anahtar = 10

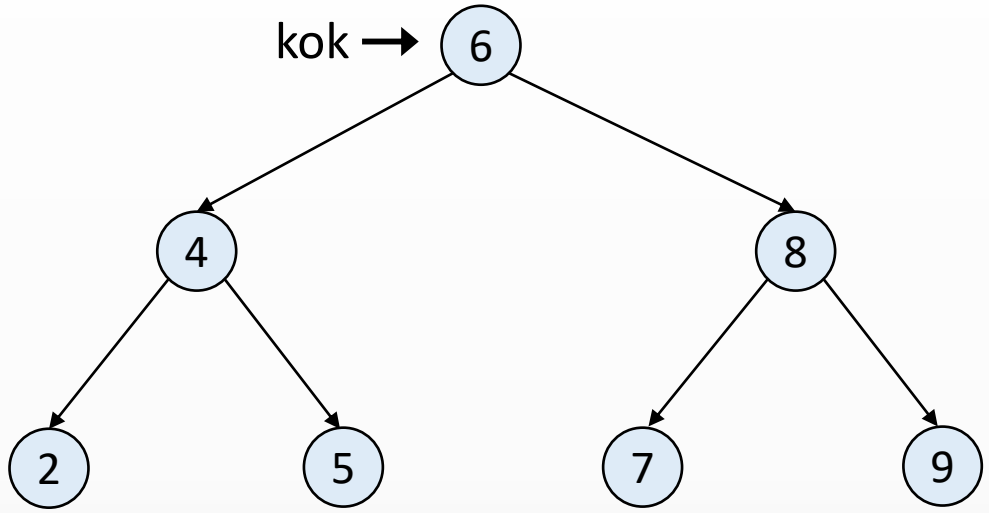
```
 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
 2 {
 3   if(kok == null || kok.veri == anahtar) {
 4     return kok;
 5   }
 6   if(anahtar < kok.veri)
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	satır no	kok	anahtar
ara		6	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 çağrımı	satır no	kok	anahtar
ara		6	10

anahtar = 10

```
 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 }
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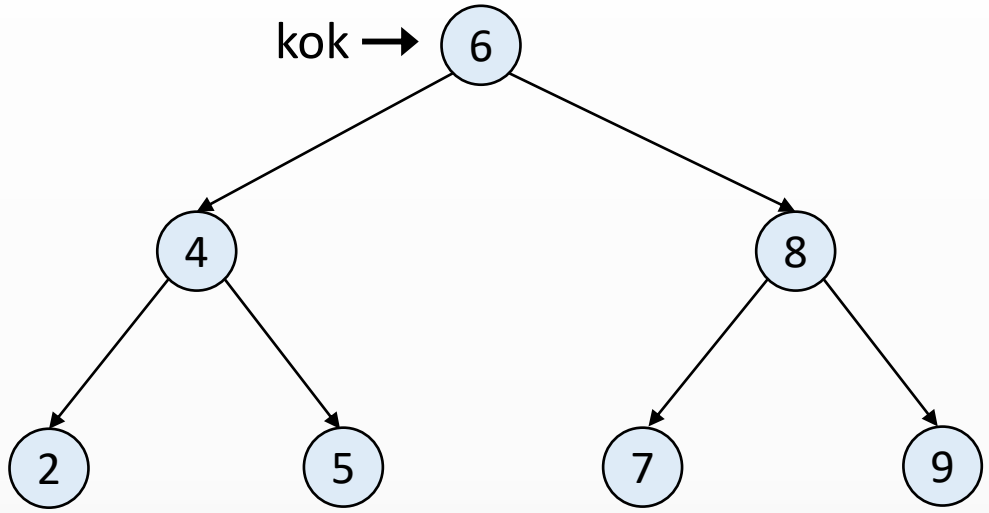

metot çağrımı	satır no	kok	anahtar
ara		6	10

anahtar = 10

```
 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
 2 {
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10 }
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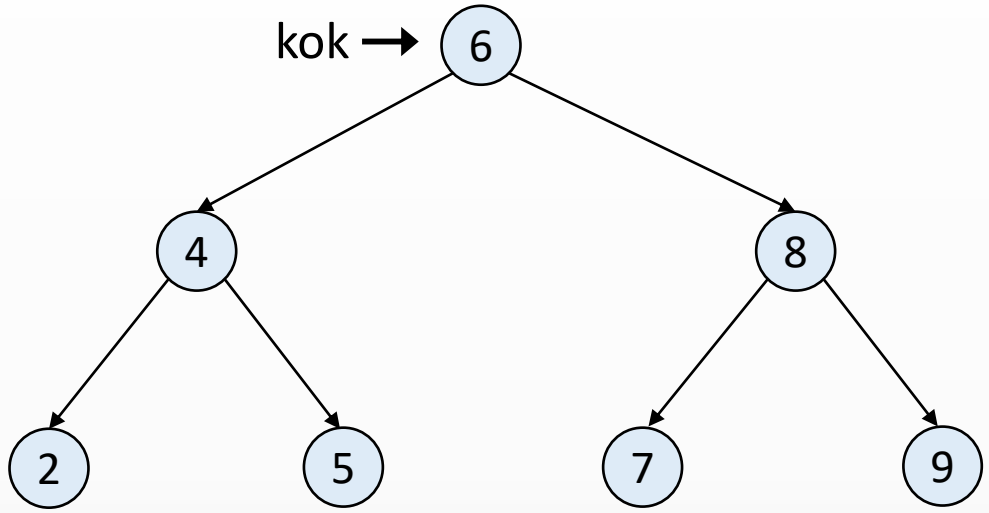

metot çağrımı	satır no	kok	anahtar
ara		6	10

anahtar = 10

```
 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);
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10 }
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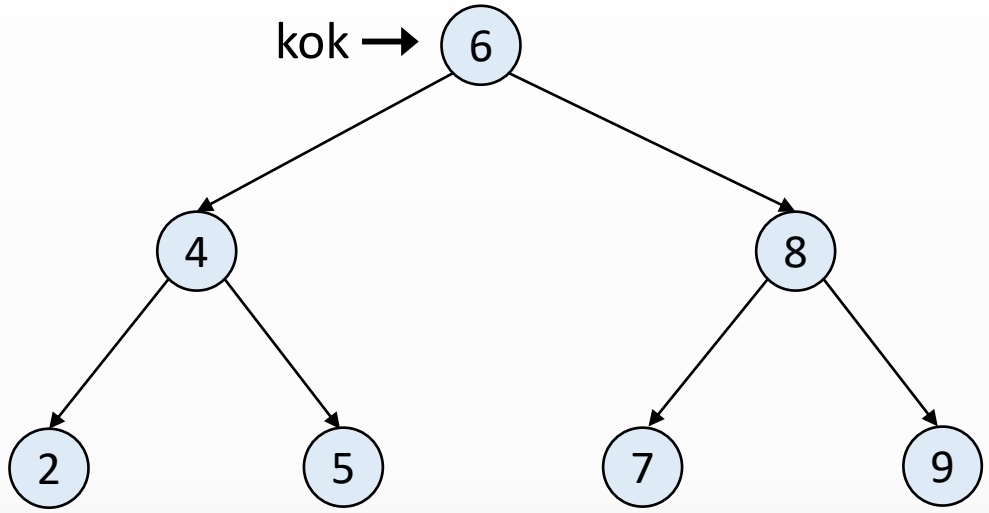

metot çağrımı	satır no	kok	anahtar
ara	9	6	10

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 }
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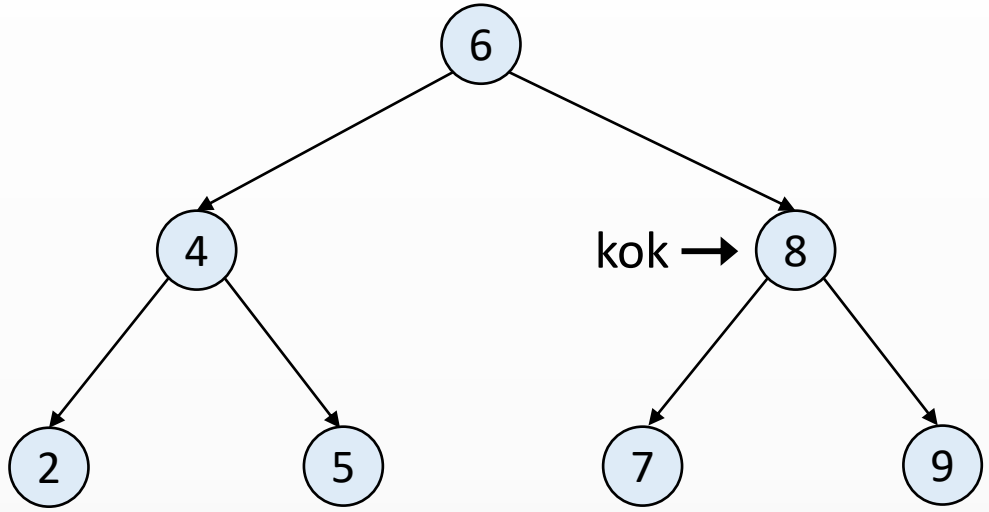

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10

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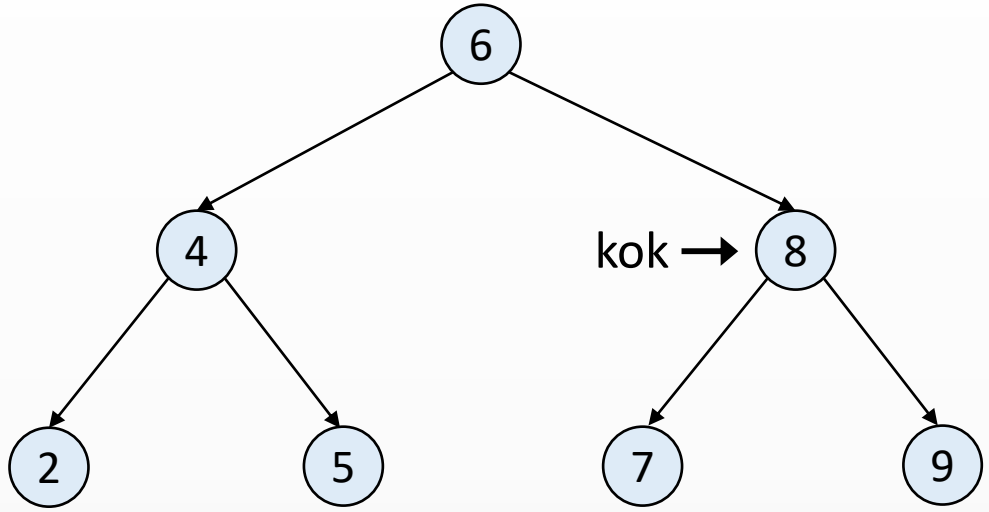
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



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

anahtar = 10

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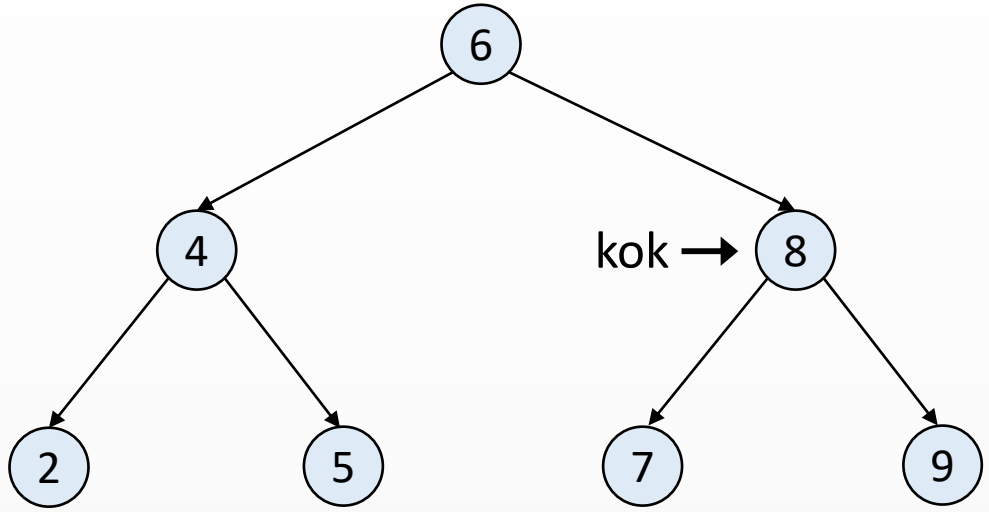

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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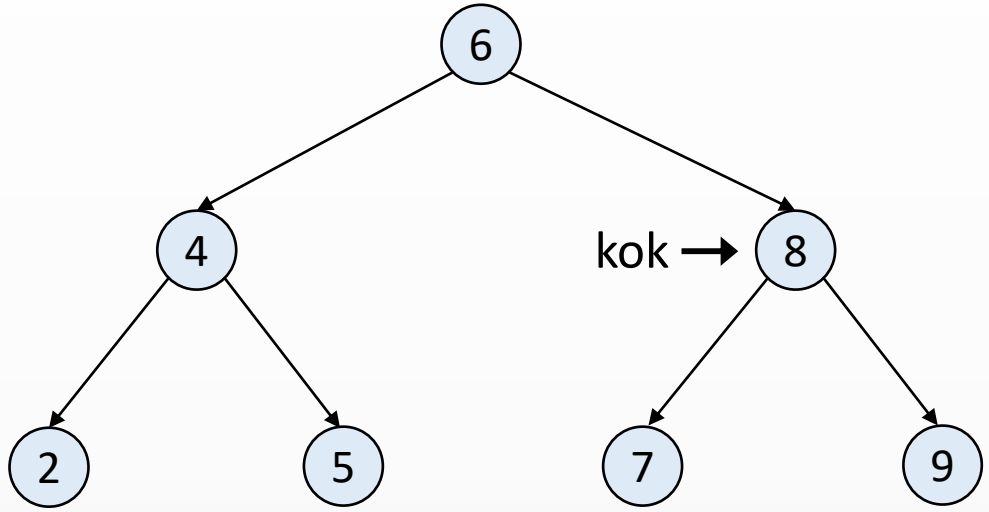

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara		8	10

anahtar = 10

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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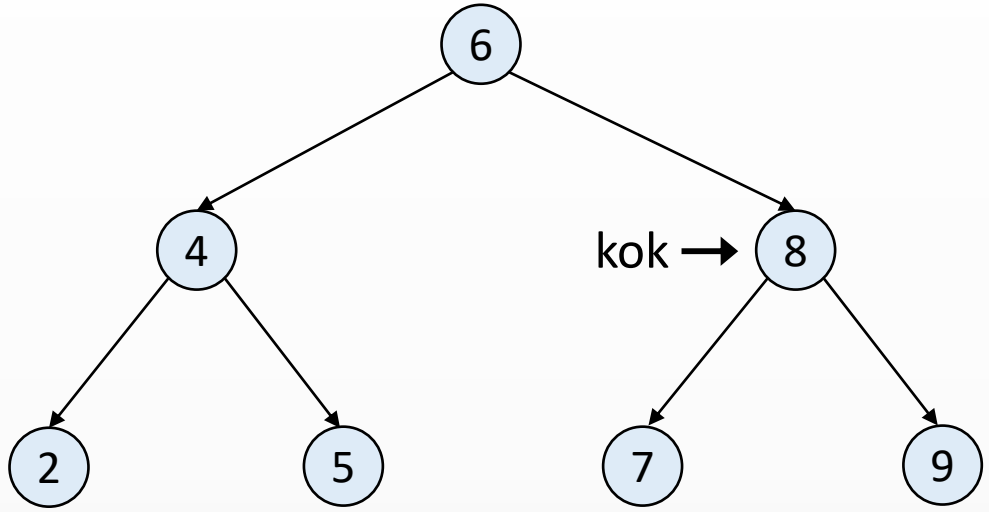

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10

anahtar = 10

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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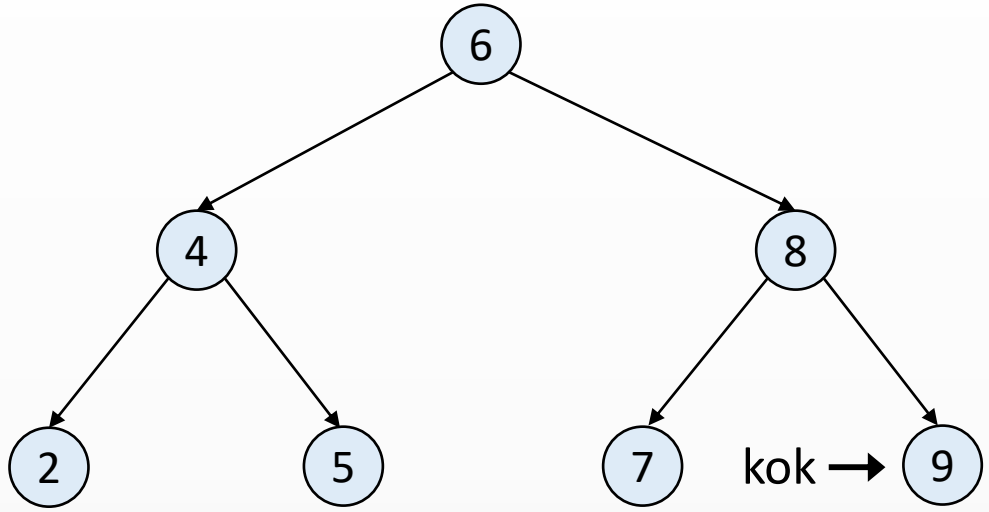

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara		9	10

anahtar = 10

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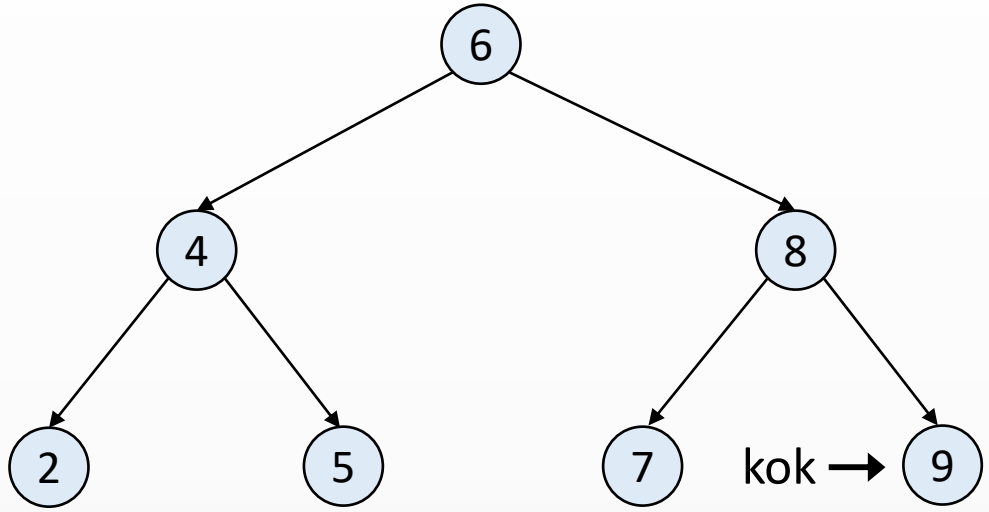

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara		9	10

anahtar = 10

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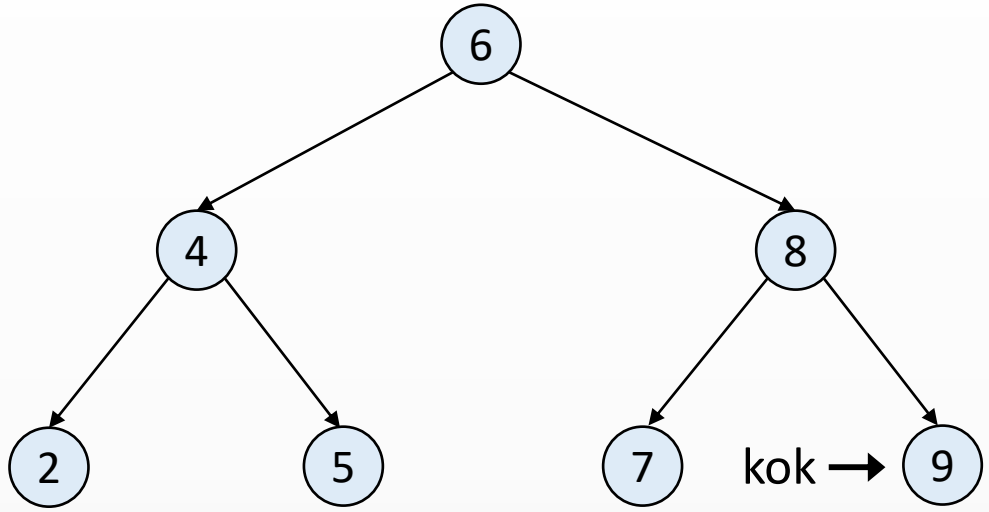
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	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)
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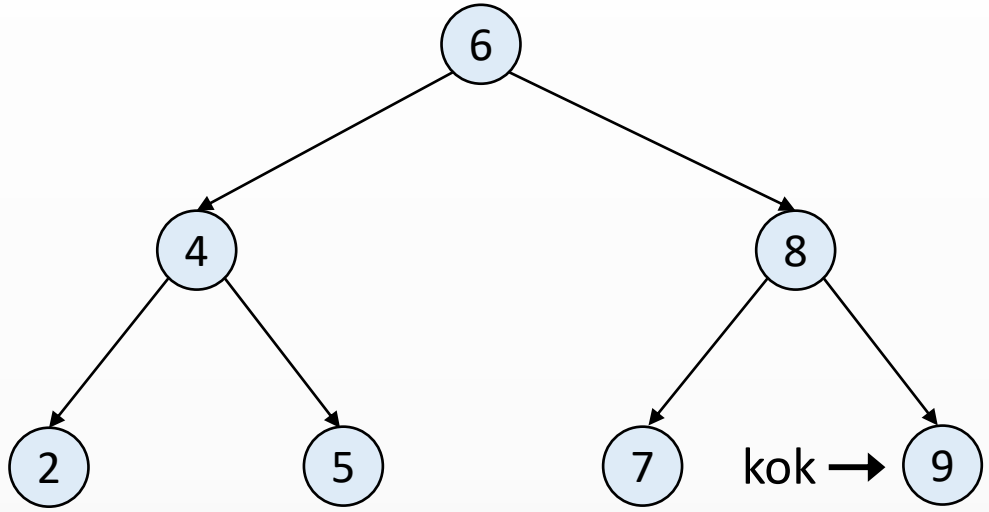

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara		9	10

anahtar = 10

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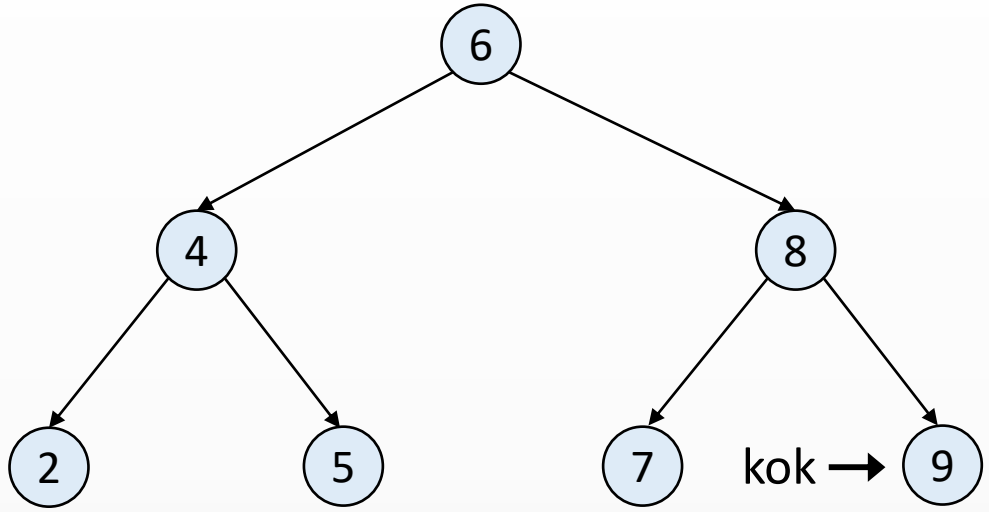

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10

anahtar = 10

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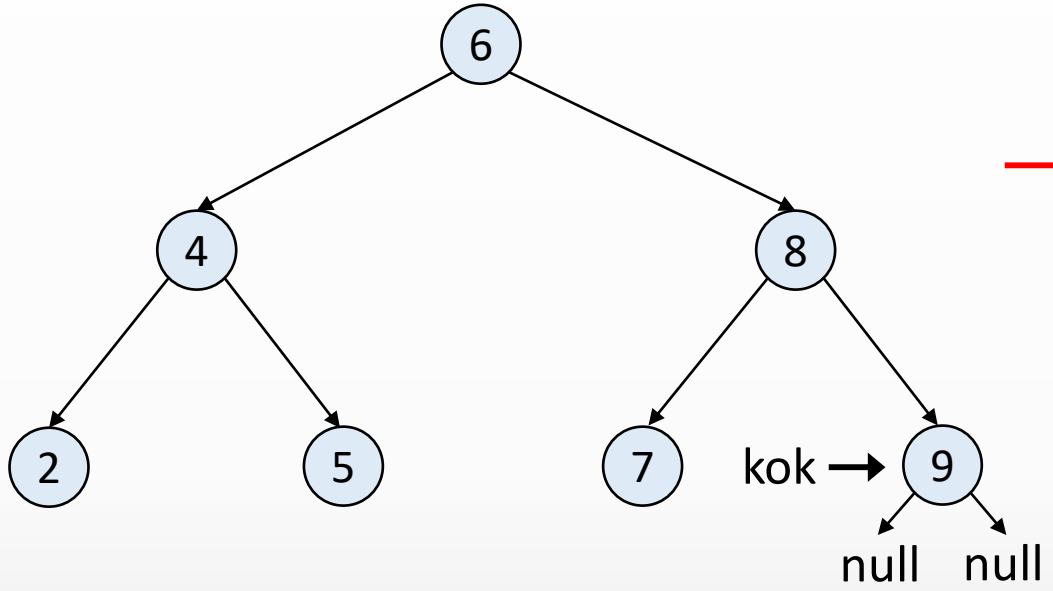
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	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   }
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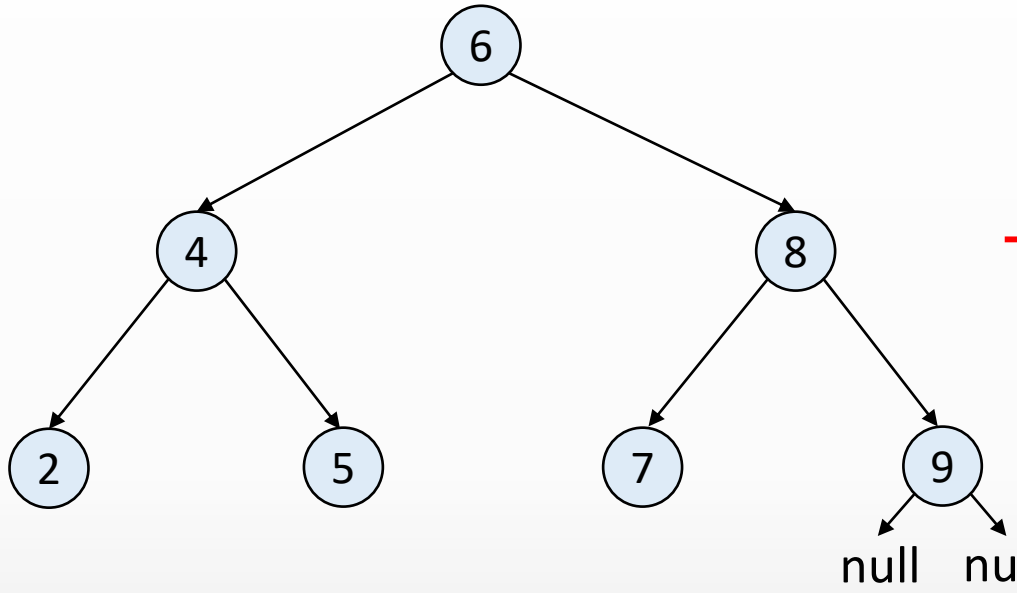
 7     return ara(kok.sol, anahtar);
 8   else
 9     return ara(kok.sag, anahtar);
10 }
```



metot çağrımı	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;
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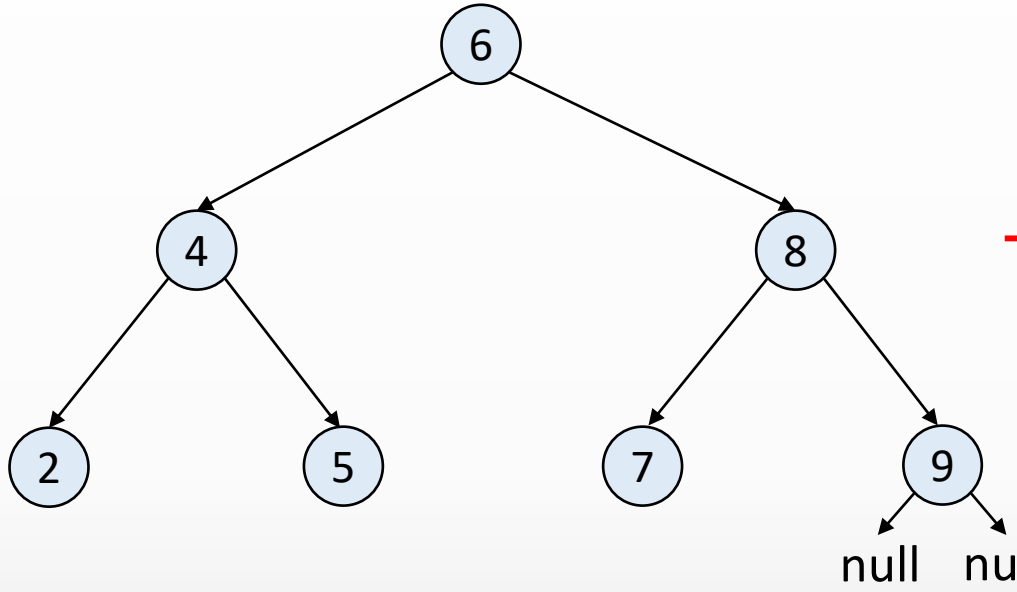

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10
ara		null	10

anahtar = 10

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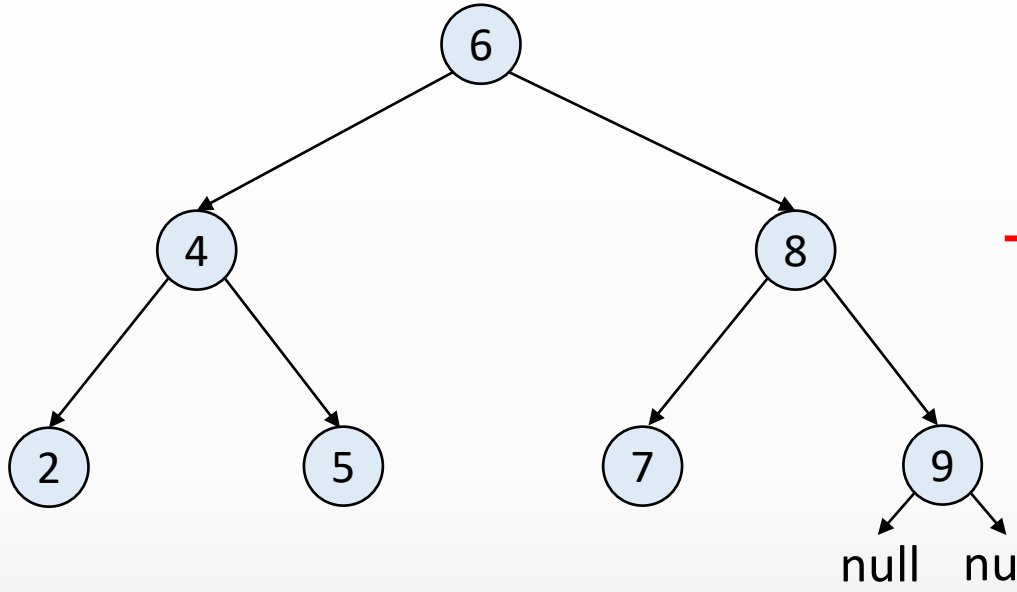

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10
ara		null	10

anahtar = 10

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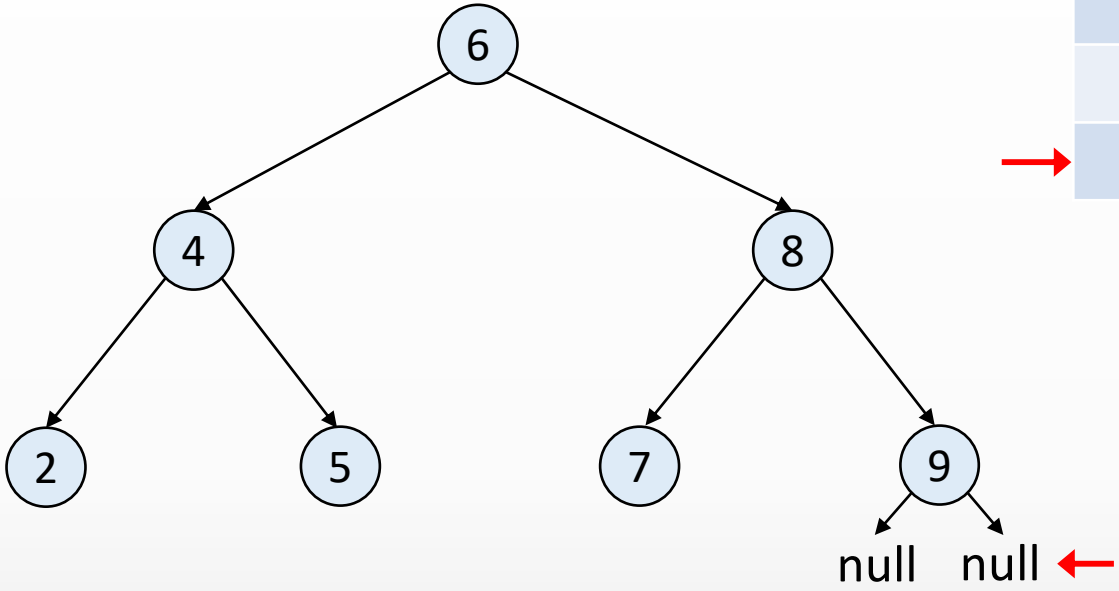

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10

anahtar = 10

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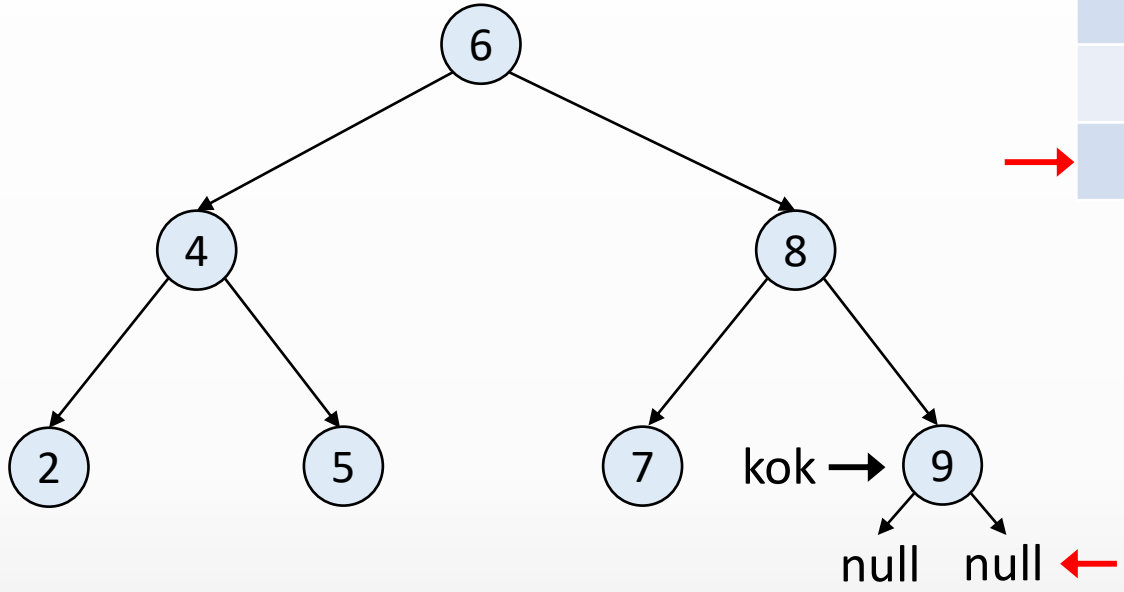

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10
ara	9	9	10

anahtar = 10

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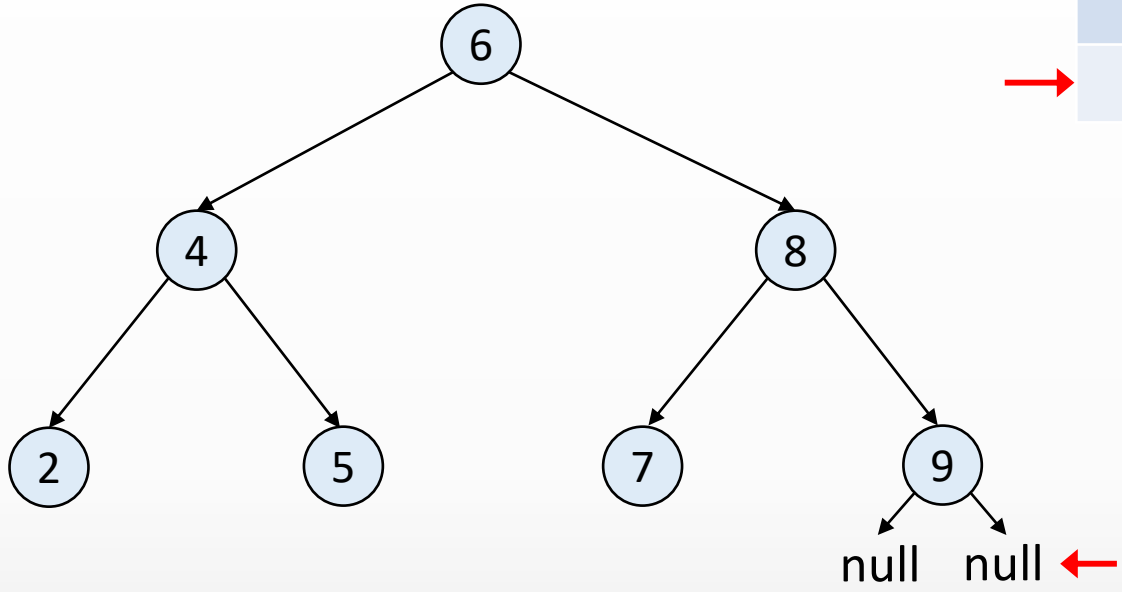

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10

anahtar = 10

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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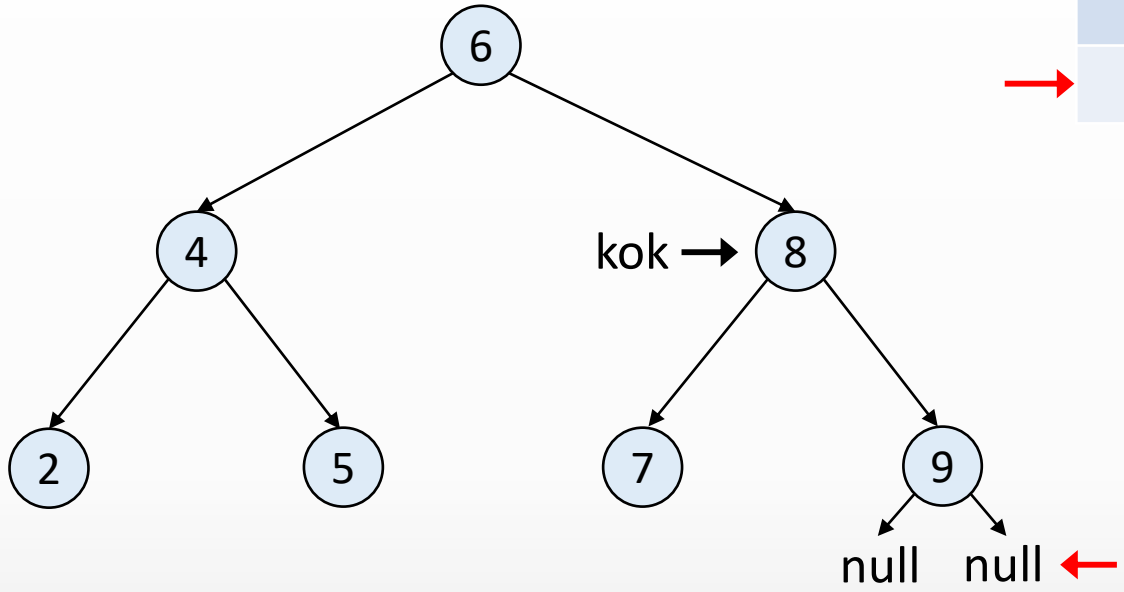

metot çağrımı	satır no	kok	anahtar
ara	9	6	10
ara	9	8	10

anahtar = 10

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 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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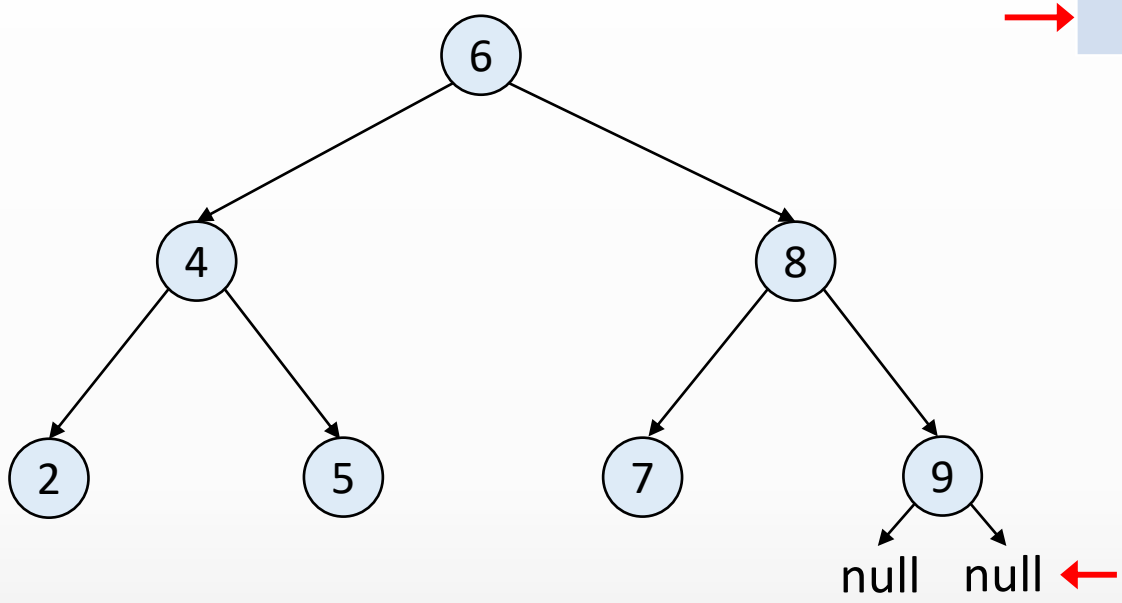
metot çağrımı	satır no	kok	anahtar
ara	9	6	10



anahtar = 10

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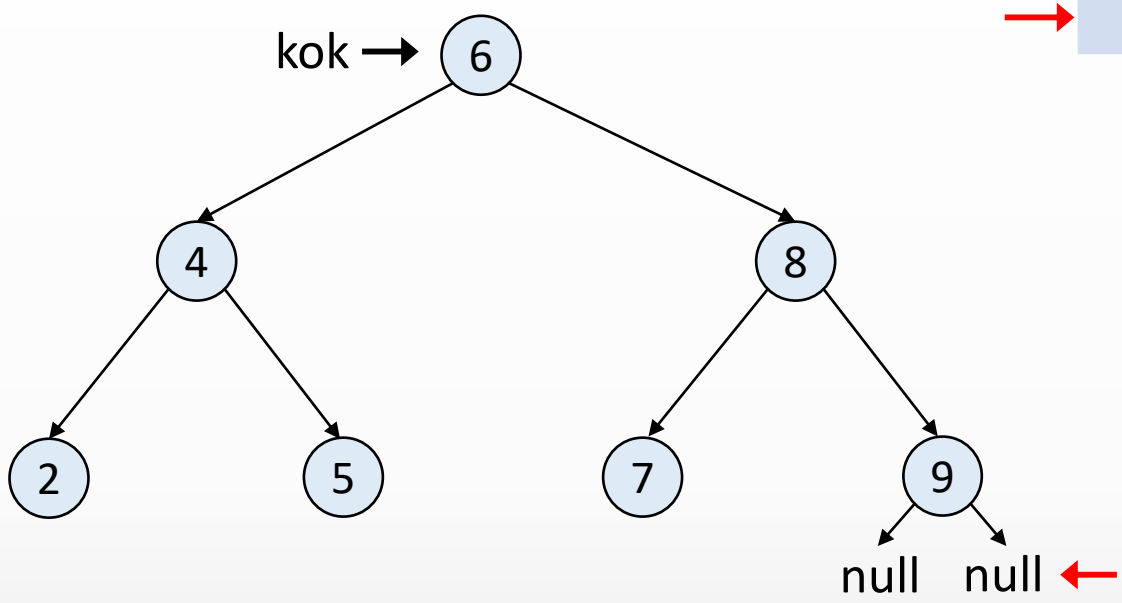
metot çağrımı	satır no	kok	anahtar
ara	9	6	10



anahtar = 10

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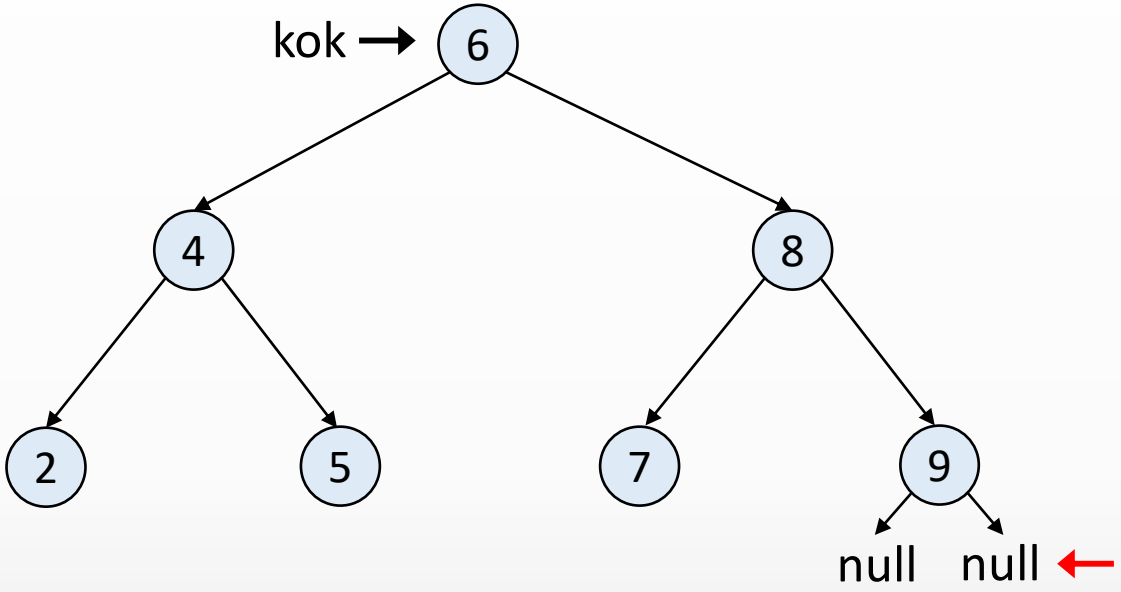

metot çağrımı	satır no	kok	anahtar

```
 1 public AgacDugumu ara(AgacDugumu kok, int anahtar)
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 9     return ara(kok.sag, anahtar);
10 }
```

Generic İkiliAgacDugum Sınıfı

```
public class IkiliAgacDugum<E extends Comparable<E>> {

  E veri;                          // Düğümün sakladığı nesne
  IkiliAgacDugum<E> solCocuk; // Sol çocuk düğümün referansı
  IkiliAgacDugum<E> sagCocuk; // Sağ çocuk düğümün referansı

  public IkiliAgacDugum(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

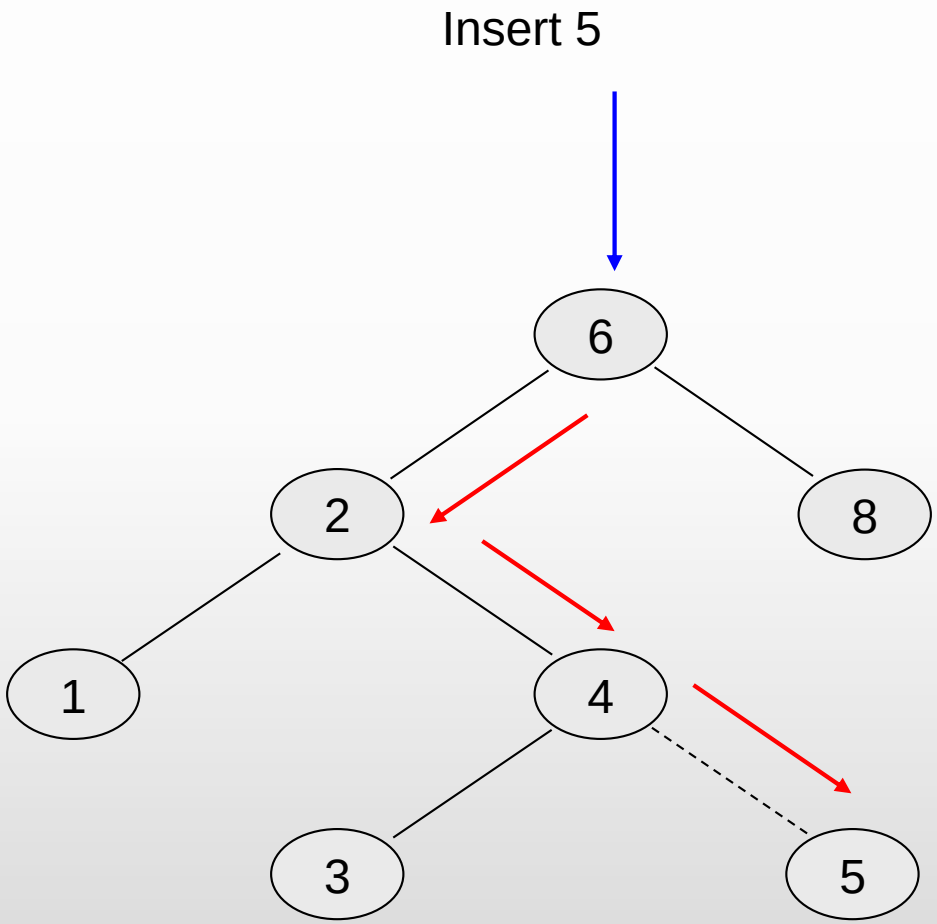
```
IkiliAgacDugum<E> minDeger(IkiliAgacDugum<E> dugum) {

  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
  }
}
```

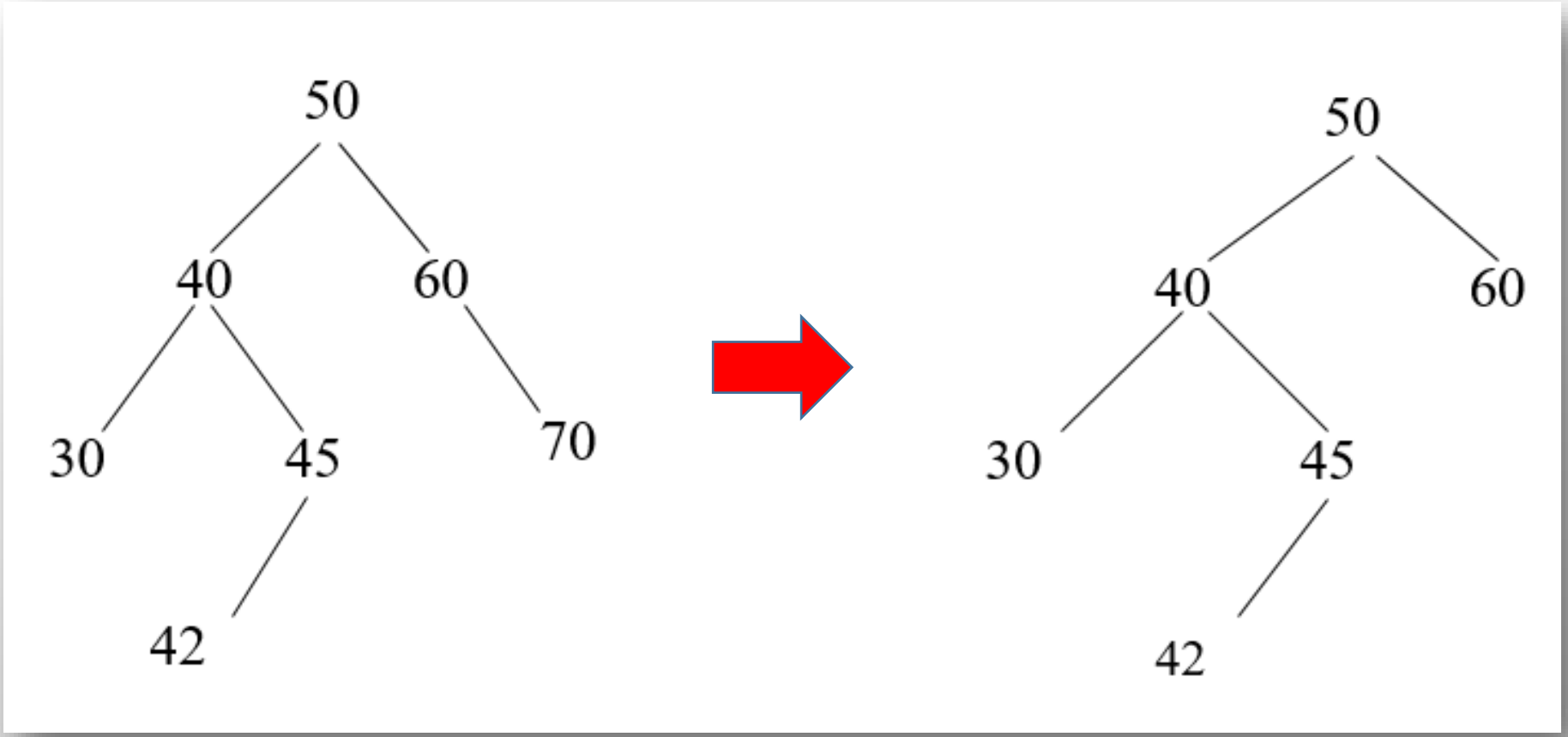
Öğe Ekleme



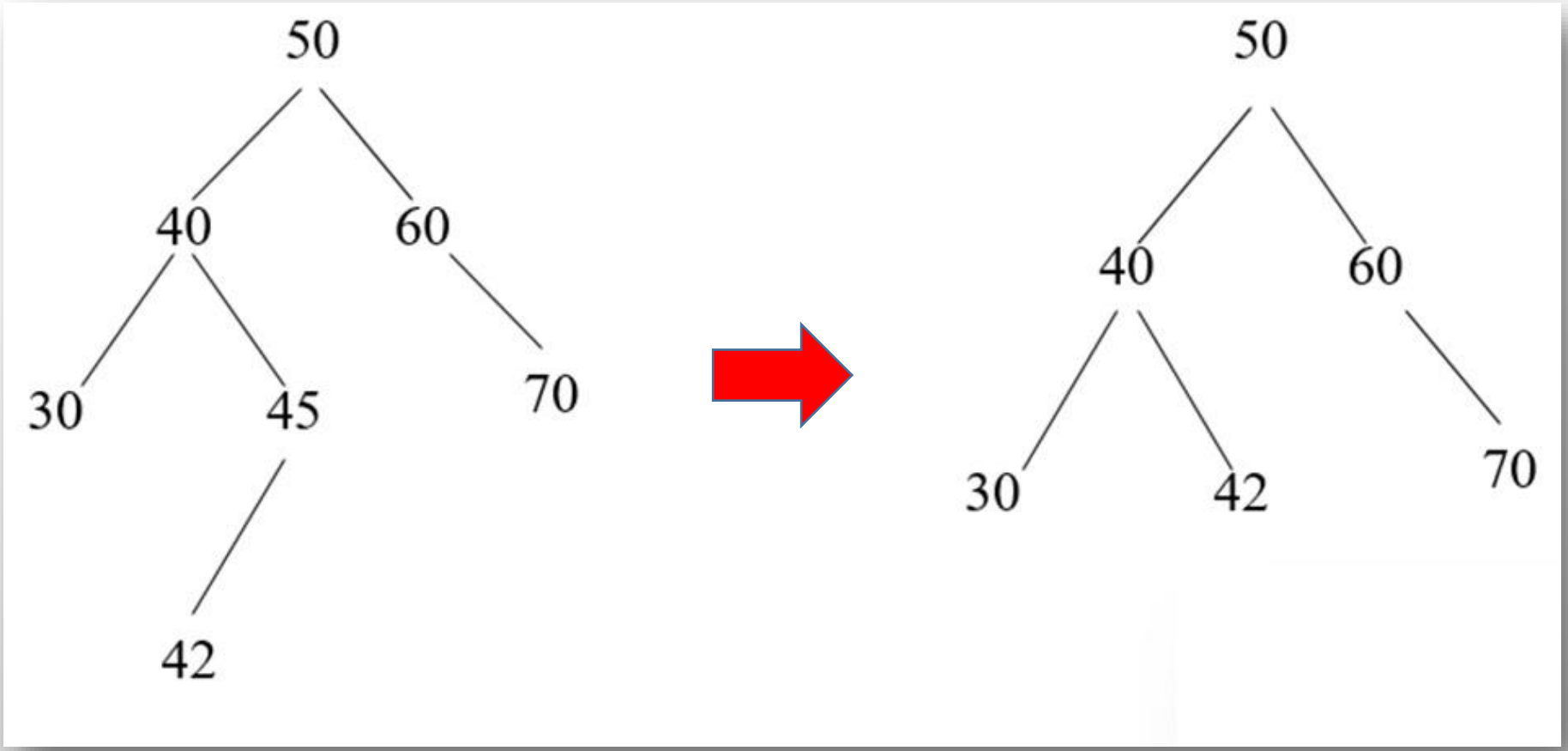
Öğe Ekleme

```
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;
}
```

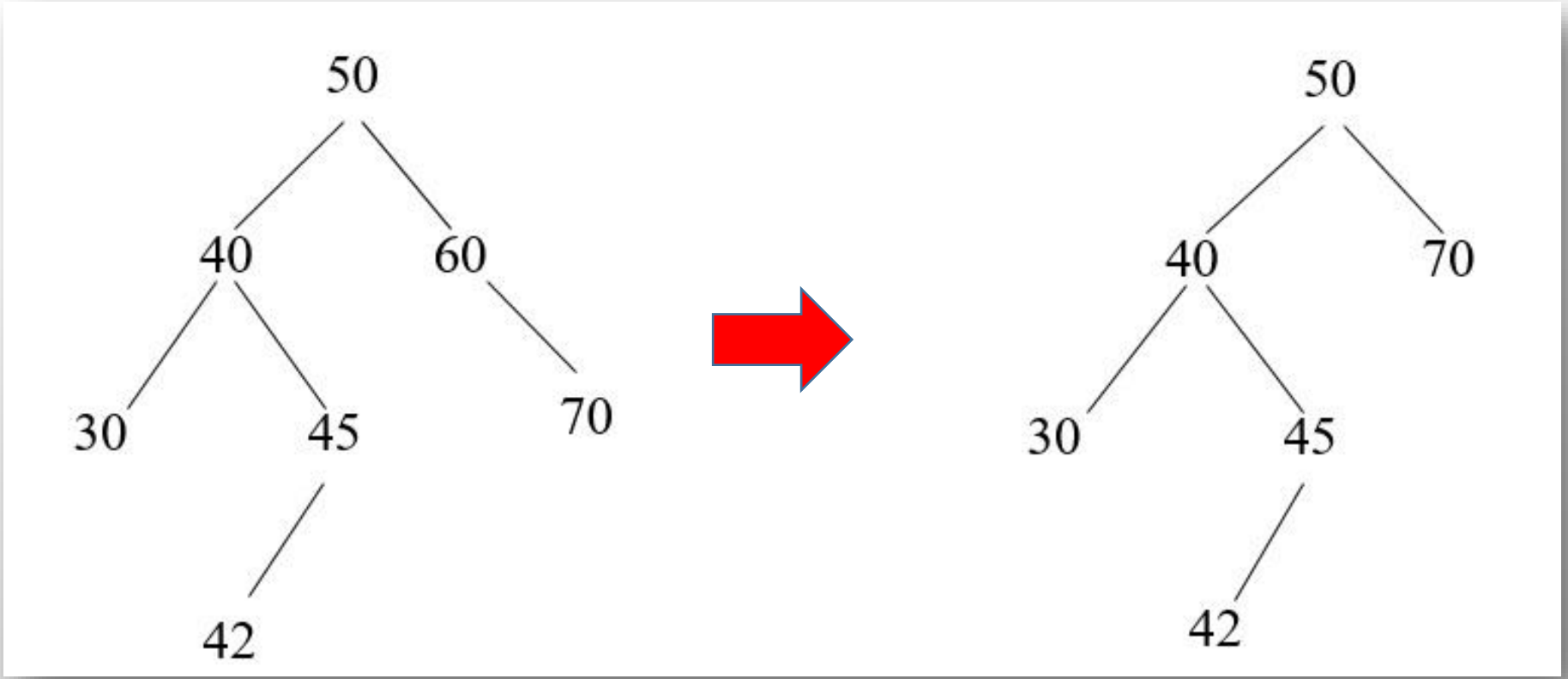
Öğe Silme – Yaprak Düğüm



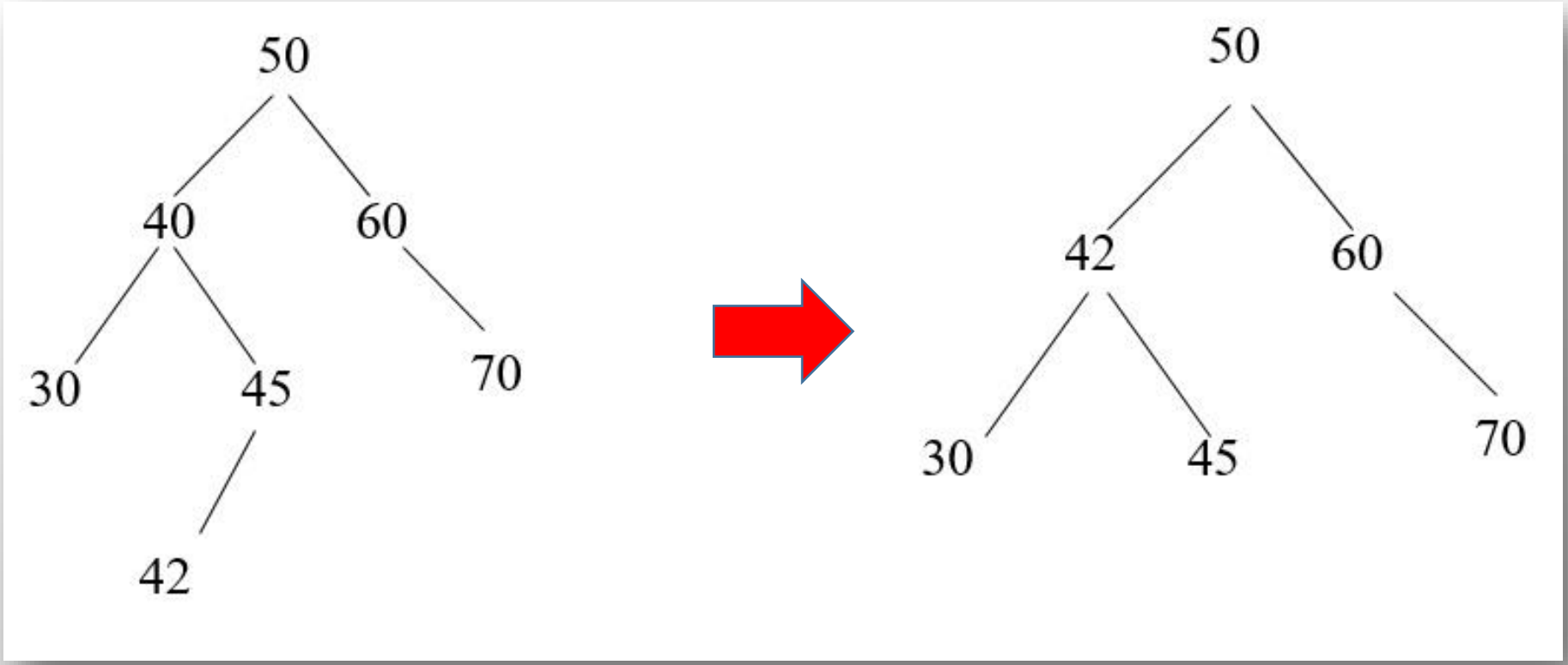
Öğe Silme – Sol Çocuğu var



Öğe Silme – Sağ Çocuğu var



Öğe Silme – Sol ve Sağ Çocuğu var



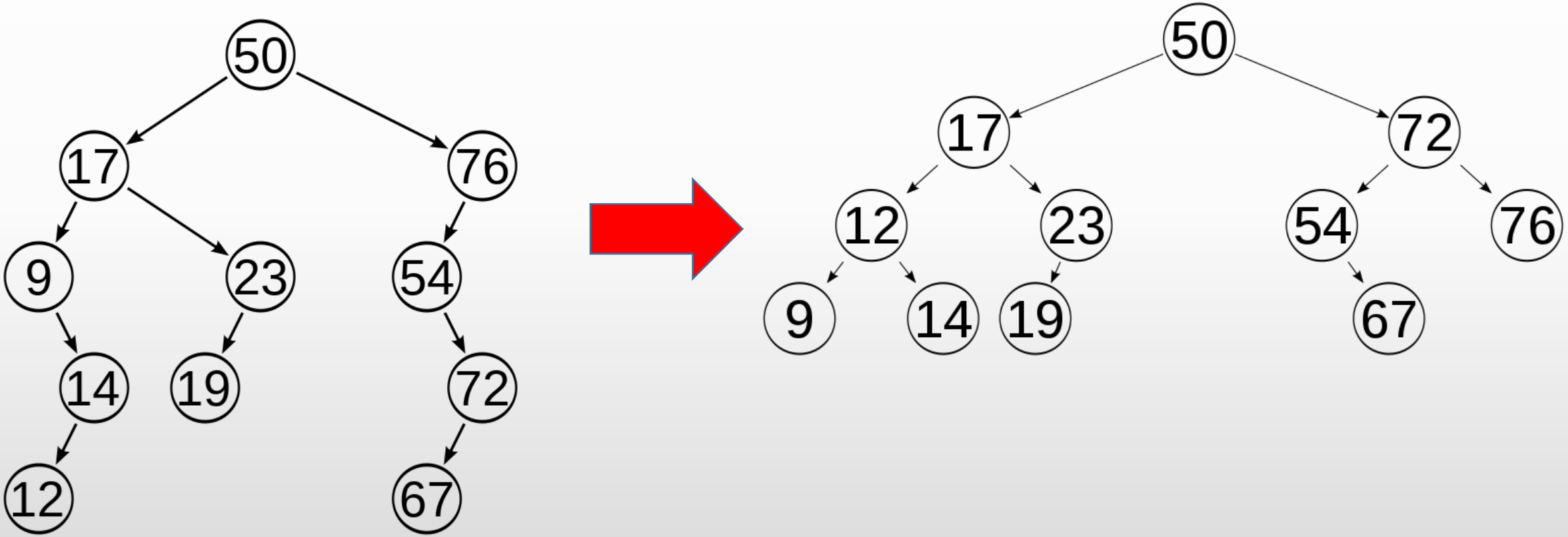
Öğe Silme

```
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;
}
```

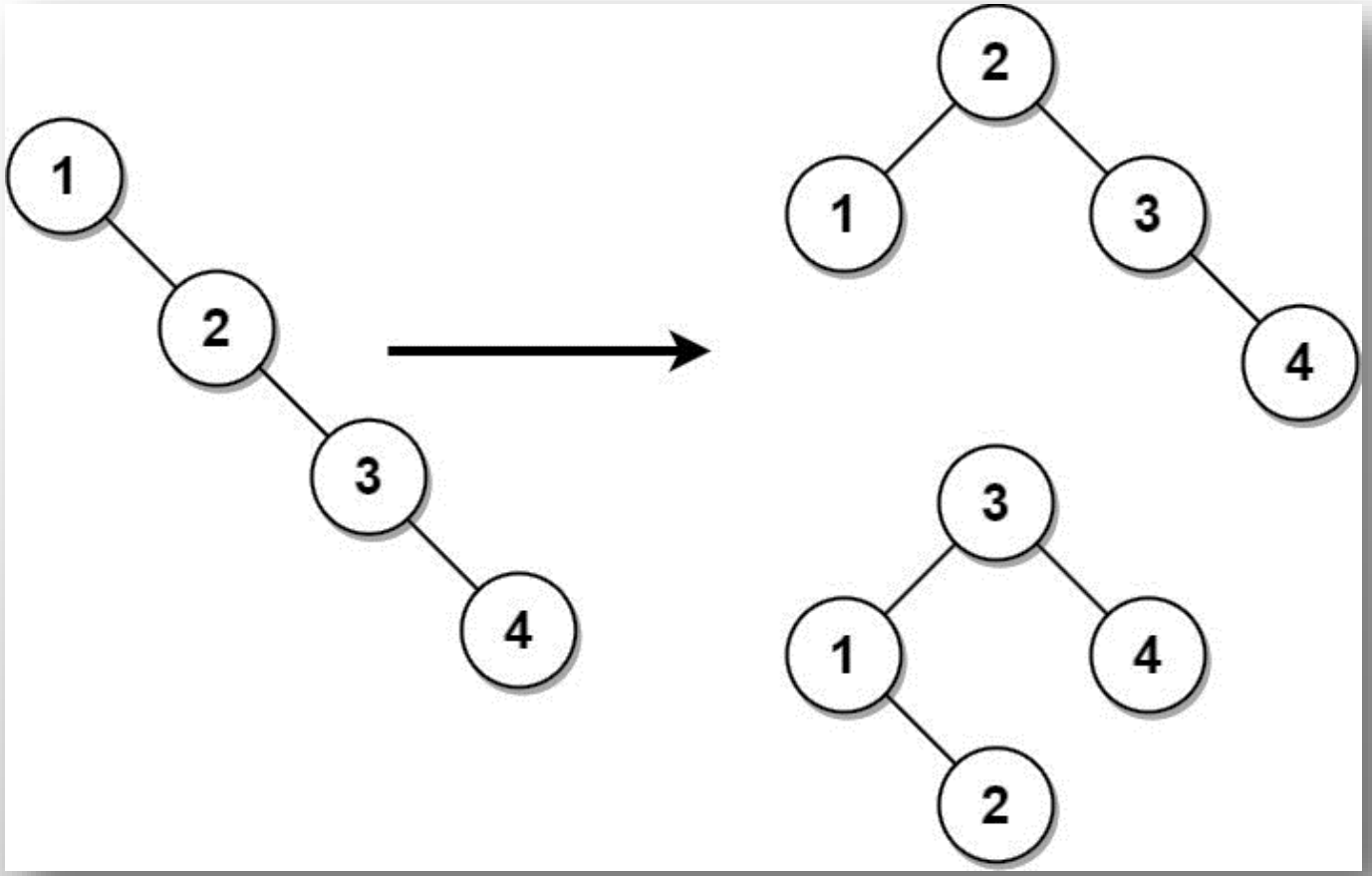
İkili Arama Ağacı İşlemlerinin Analizi

- 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("Ağaçta  "  +  kok.ogr.ogrenciNo  +  "
bulundu.");
return true;
} else if (kok.ogr.ogrenciNo > numara) {
return  ara(kok.solCocuk,  numara);  //  Aranan  veri,  düğümün
verisinden küçükse sol alt ağaçta arama yap
} else {
return  ara(kok.sagCocuk,  numara);  //  Aranan  veri,  düğümün
verisinden büyükse sağ alt ağaçta arama yap
}
}
```

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