UNIVERSITAS Dinamika

ALGORITMA PEMROGRAMAN
Pertemuan XII

SORTING

Oleh
Achmad Arrosyidi

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MATERI KULIAH

1. Bubble Sort
2. Selection Sort
3. Merge Sort
4. Quick Sort
5. Insertion Sort
6. Shell Sort
7. Radix Sort

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TUJUAN PEMBELAJARAN

Umum:

- ✓ Mahasiswa dapat menguraikan logika berbagai jenis Algoritma Pengurutan (Sorting).

Khusus:

- ✓ Mahasiswa dapat menerapkan logika berbagai jenis Algoritma Pengurutan (Sorting).

1. BUBBLE SORT

BUBBLE SORT

An Animated Example

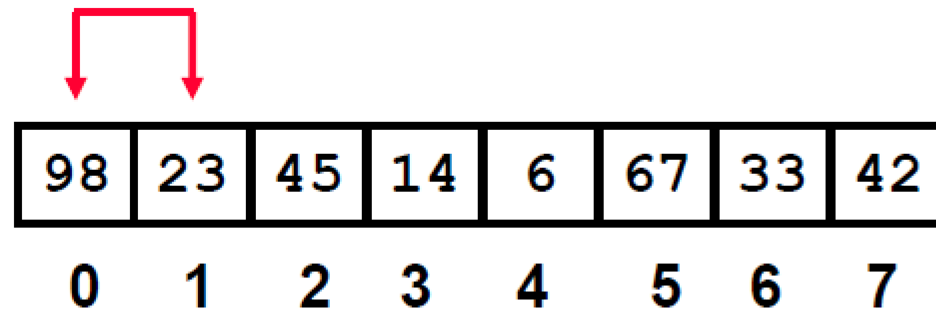
N	8
pos_akhir	6
index	

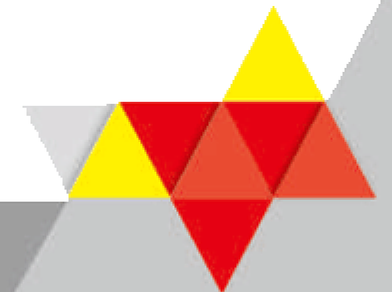
did_swap	true

98	23	45	14	6	67	33	42
0	1	2	3	4	5	6	7

An Animated Example

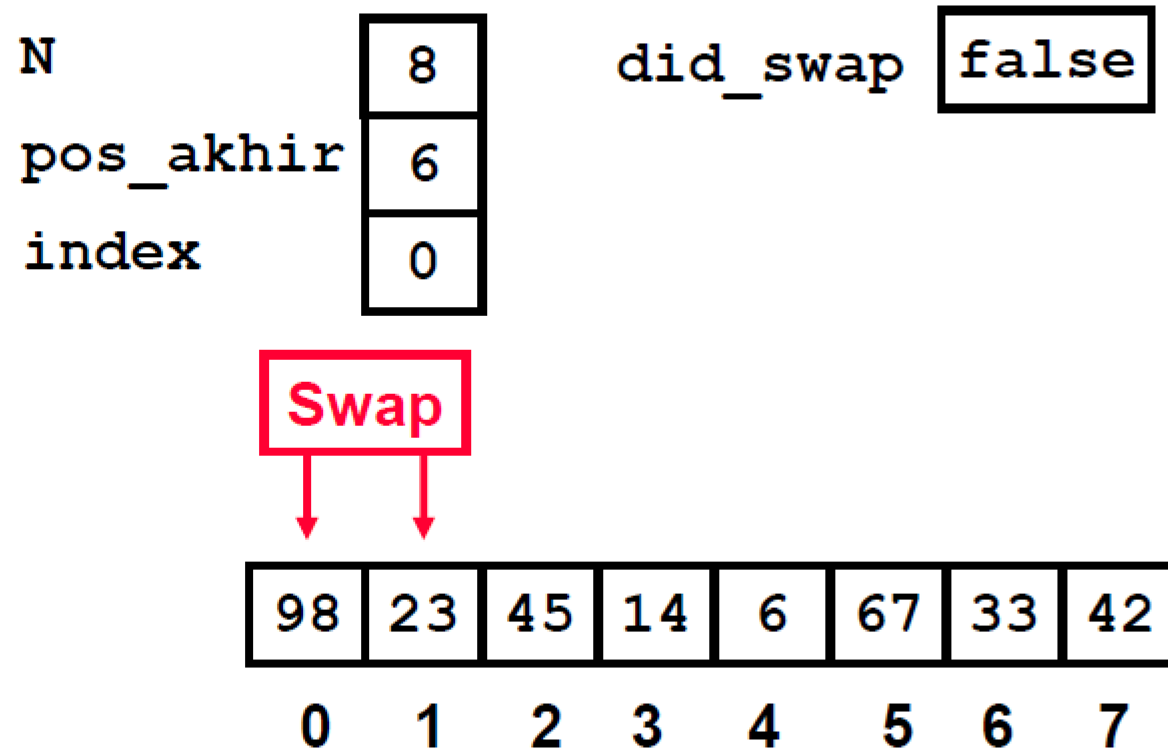
N	8	did_swap	false
pos_akhir	6		
index	0		

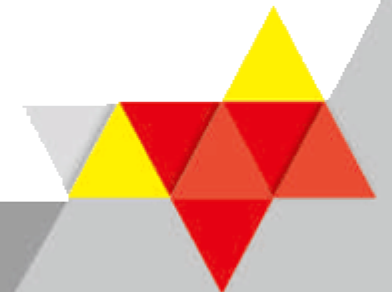




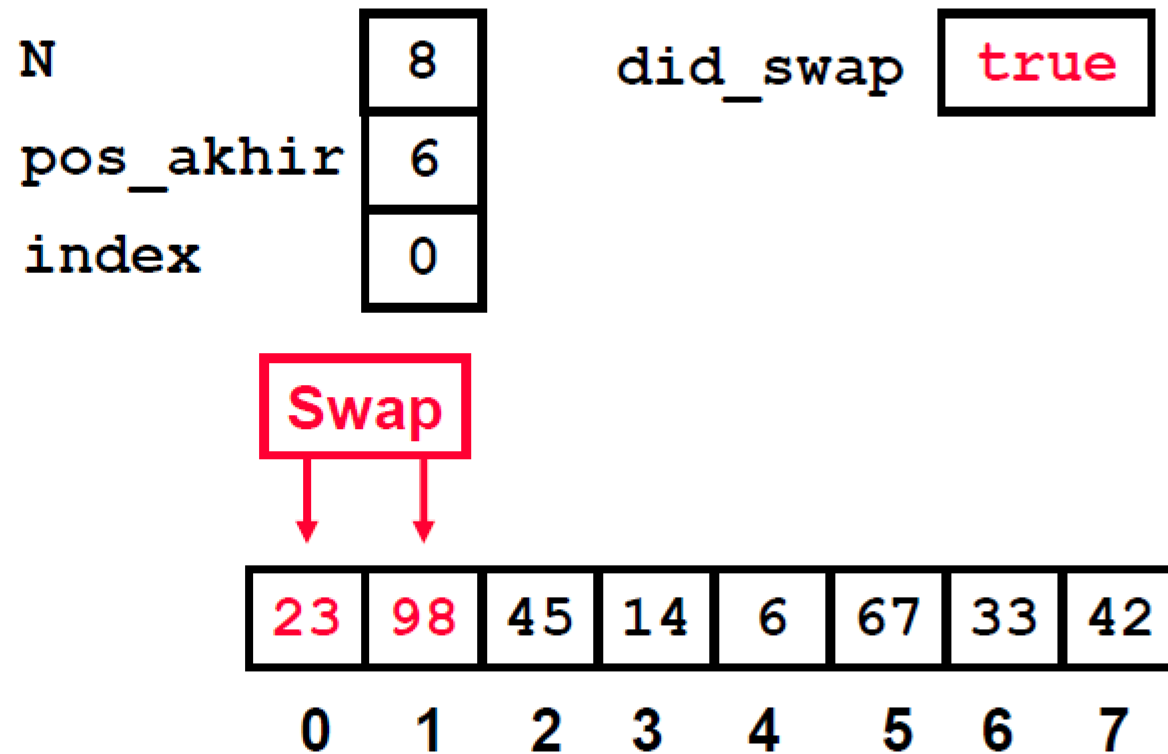
BUBBLE SORT

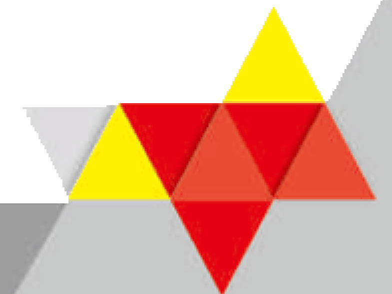
An Animated Example





An Animated Example

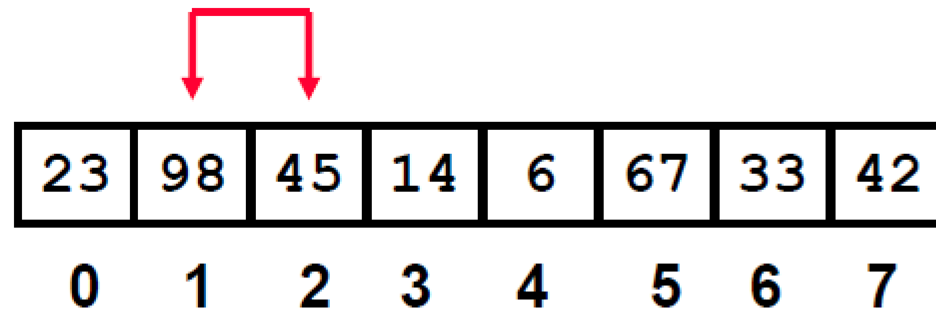


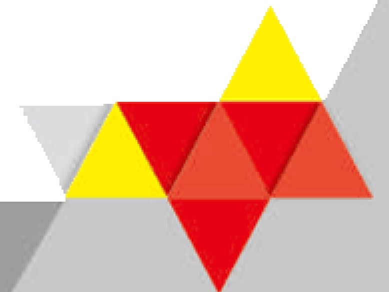


An Animated Example

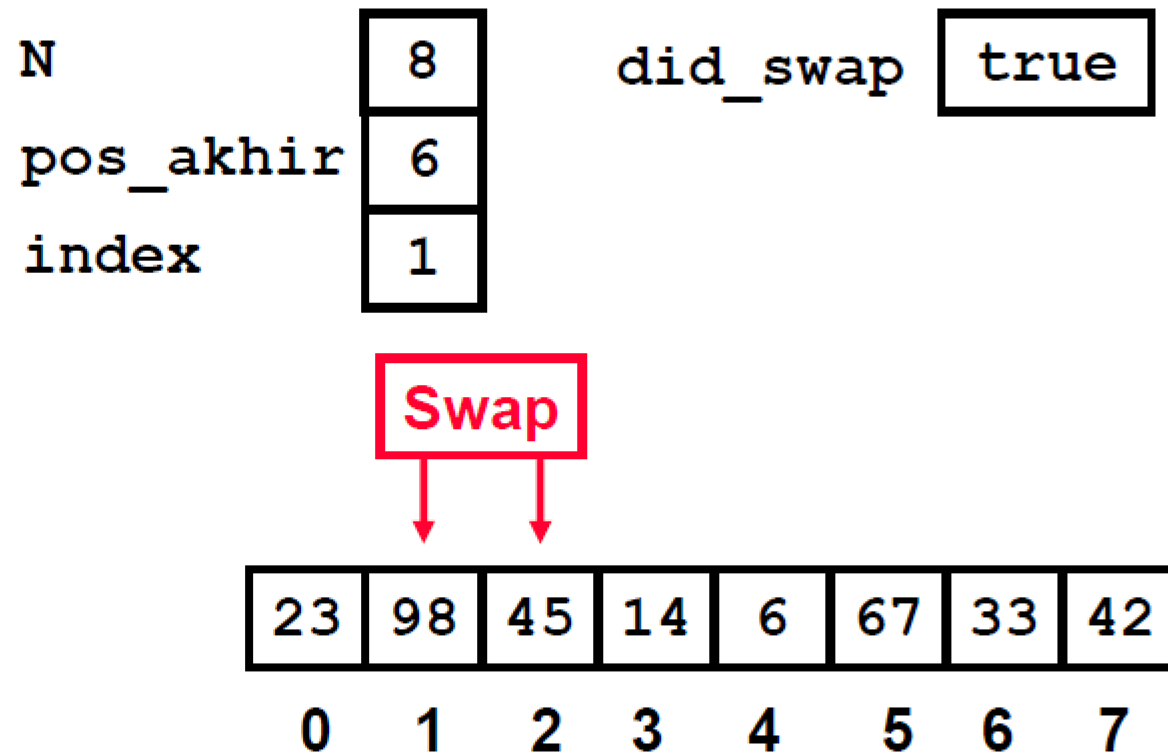
N	8
pos_akhir	6
index	1

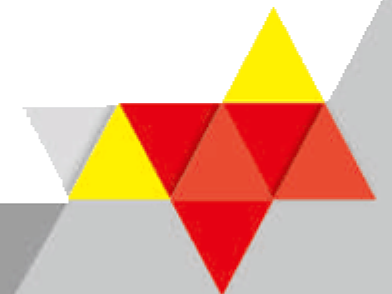
did_swap	true





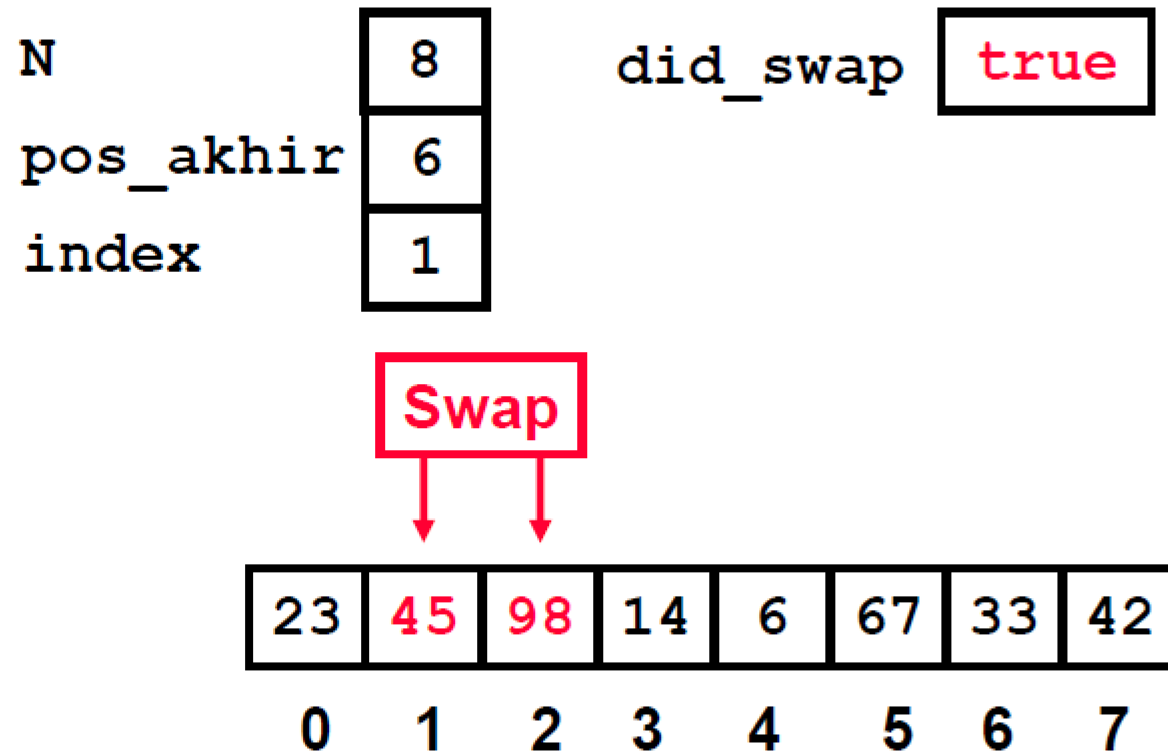
An Animated Example

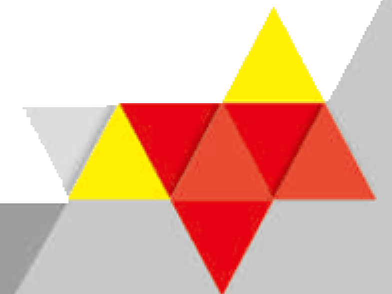




BUBBLE SORT

An Animated Example

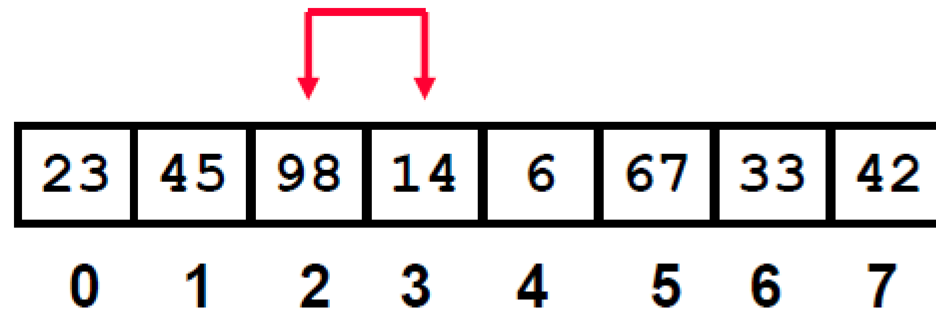


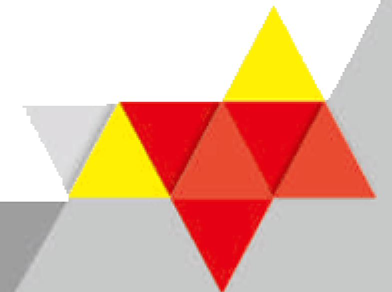


An Animated Example

N	8
pos_akhir	6
index	2

did_swap	true





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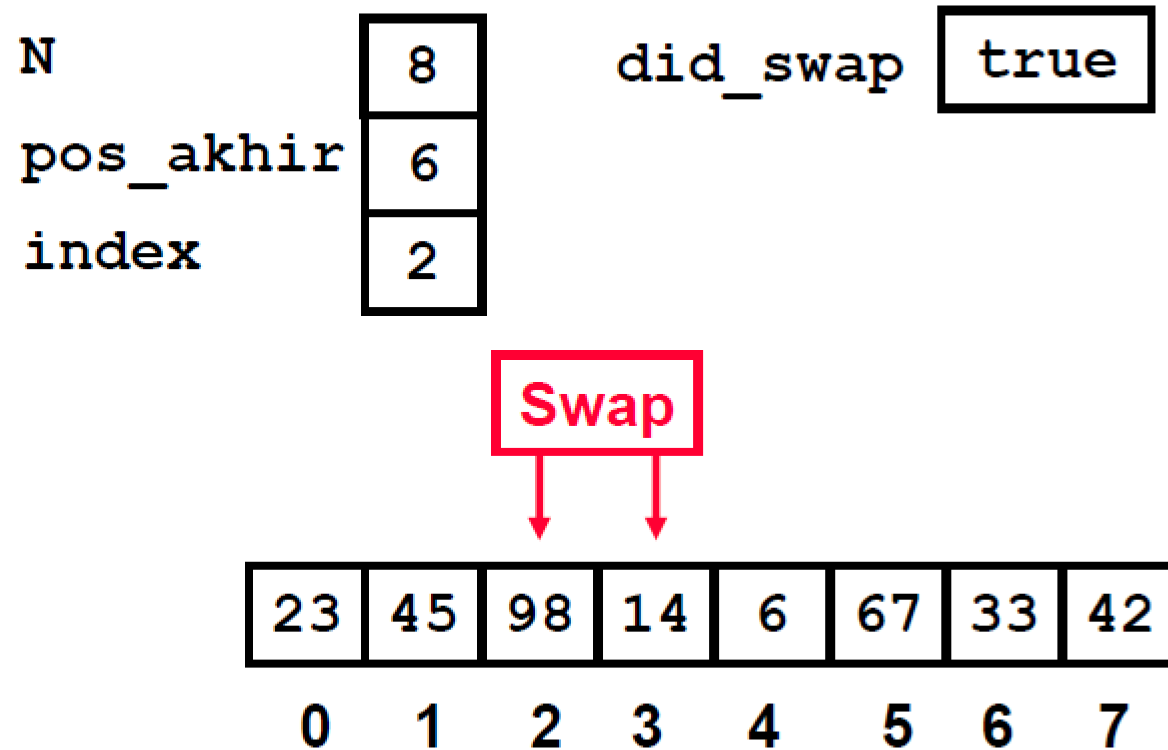
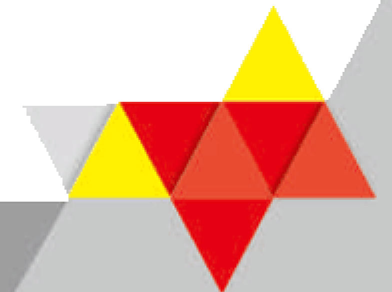
BUBBLE SORT

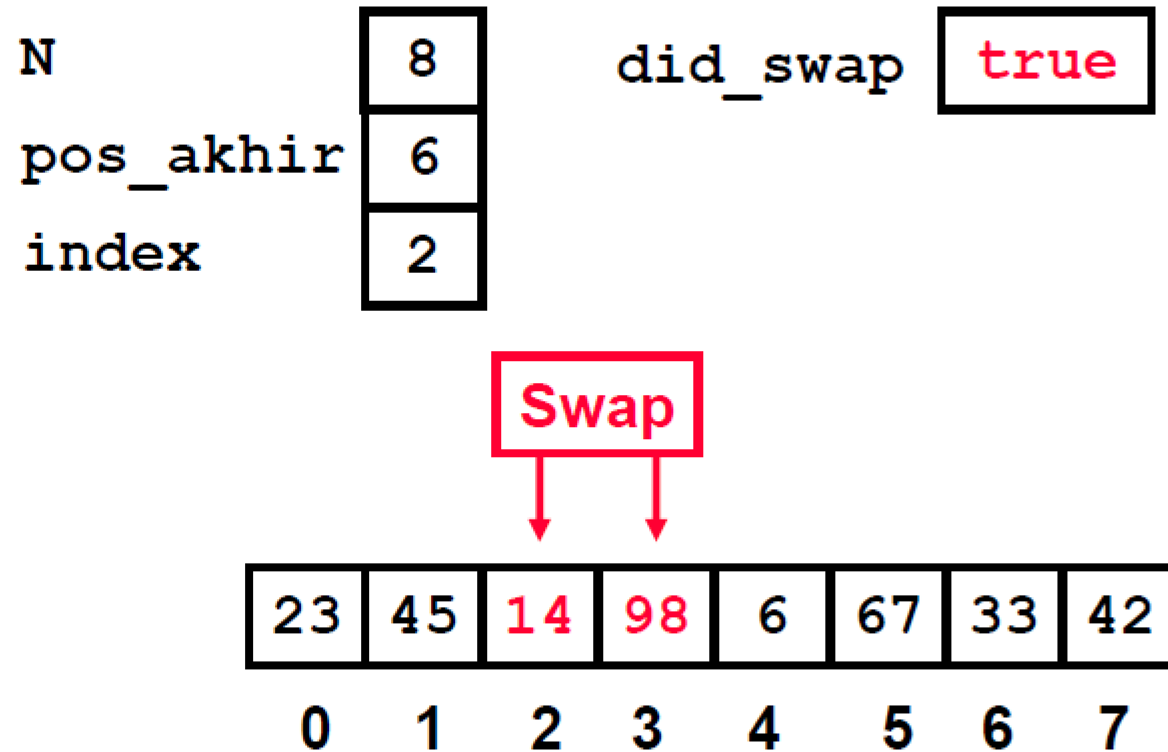
An Animated Example

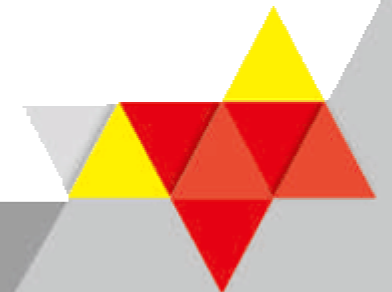




BUBBLE SORT

An Animated Example

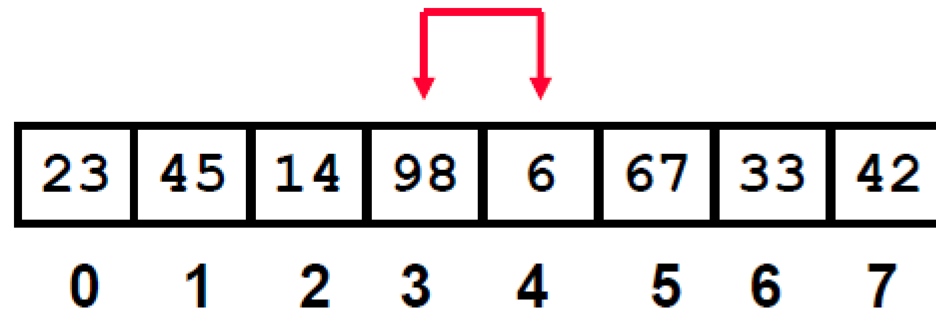


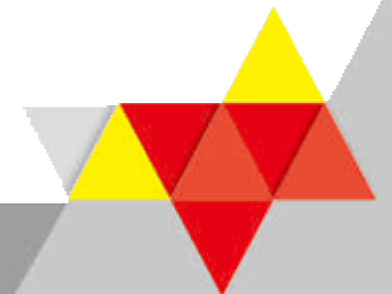


An Animated Example

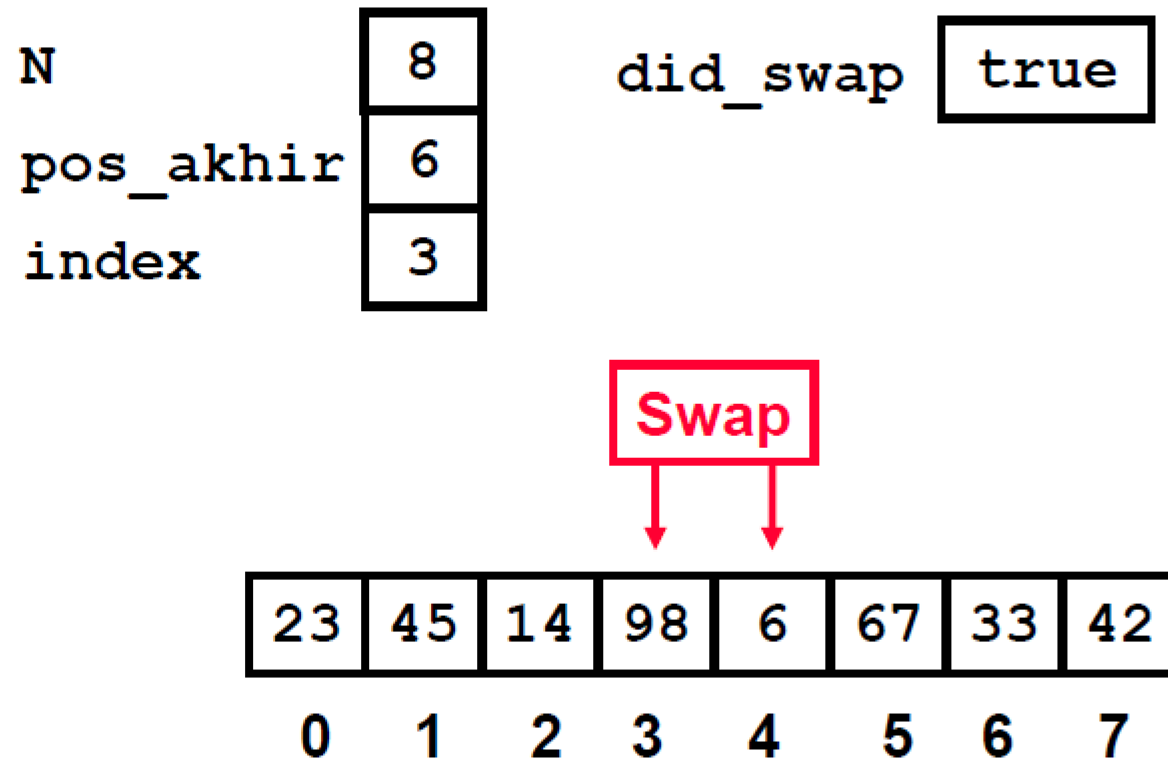
N	8
pos_akhir	6
index	3

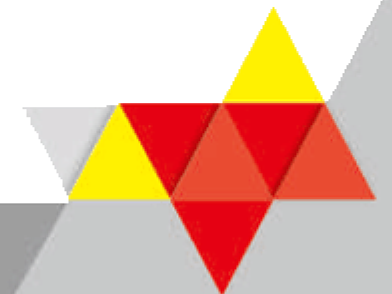
did_swap	true



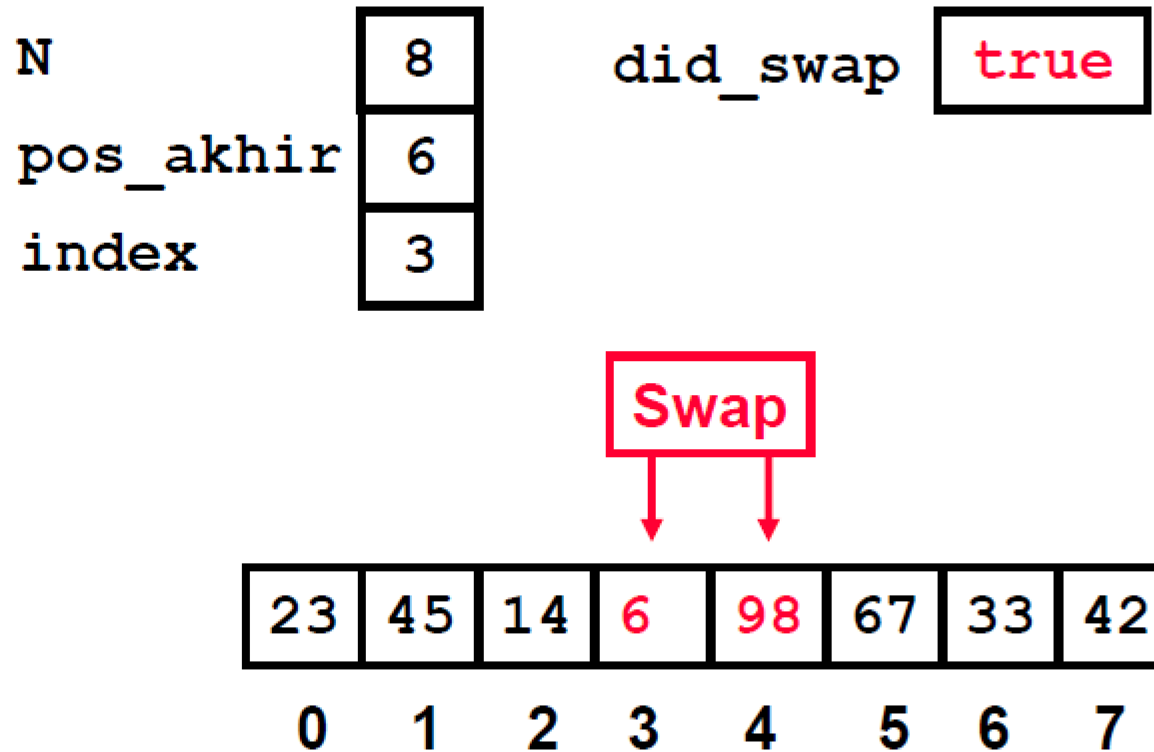


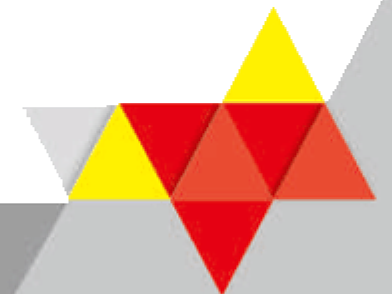
An Animated Example





An Animated Example





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BUBBLE SORT

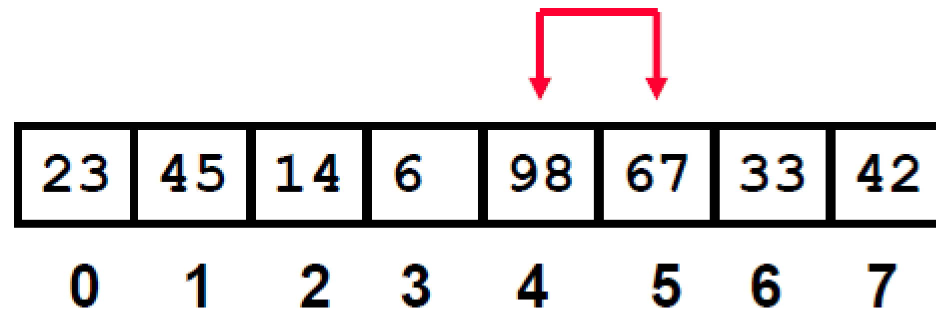
An Animated Example

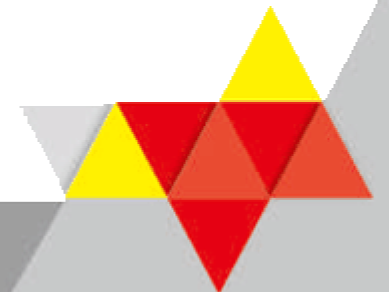
N 8

pos_akhir 6

index 4

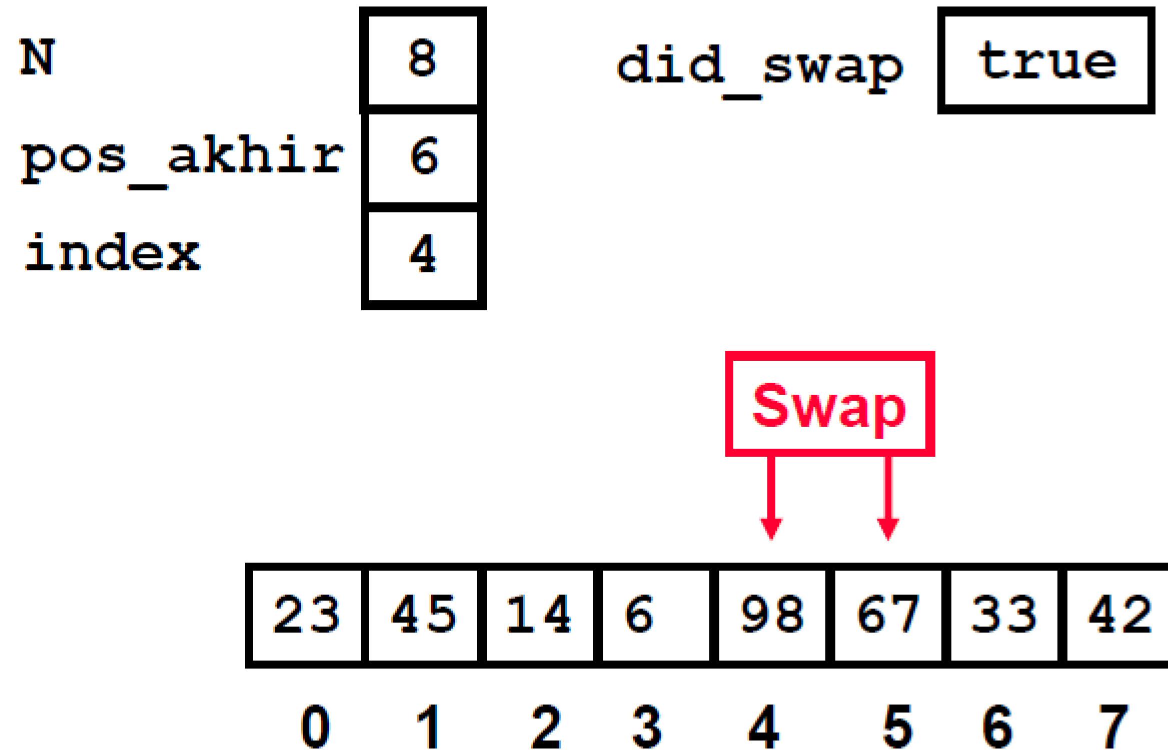
did_swap true

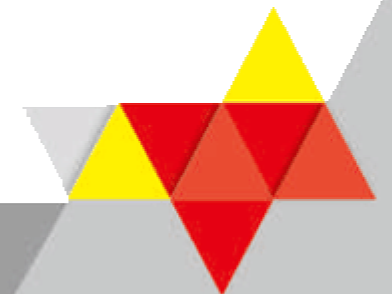




BUBBLE SORT

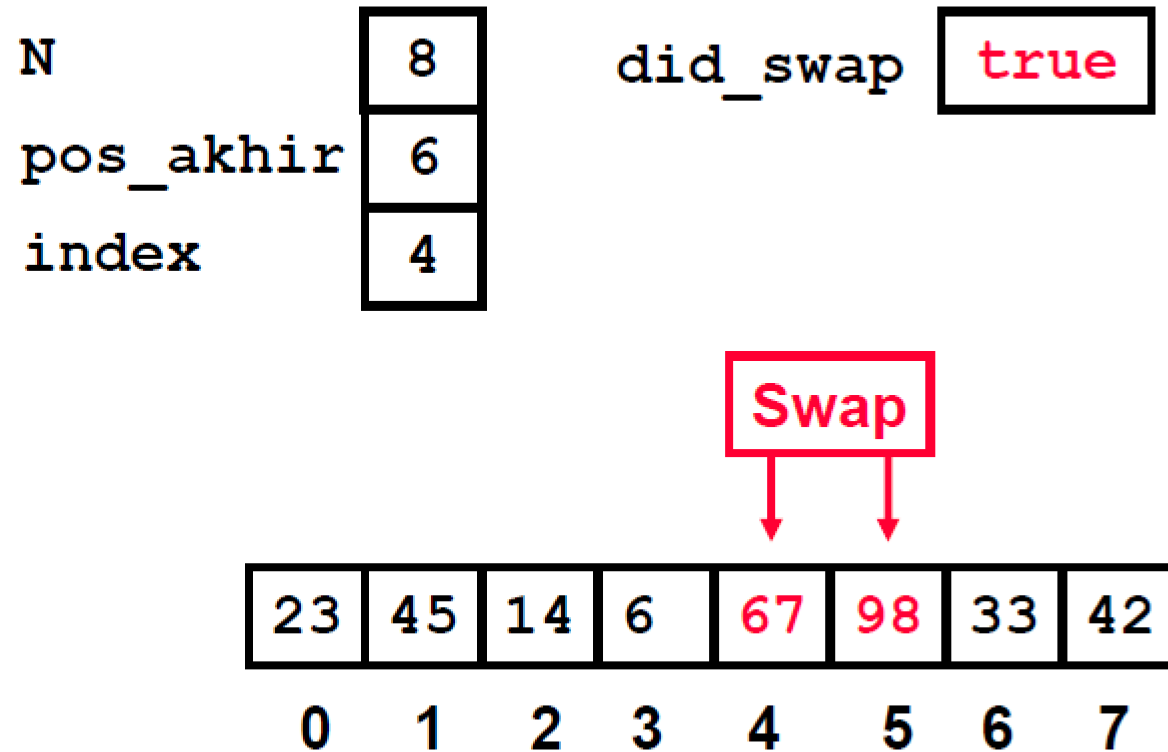
An Animated Example

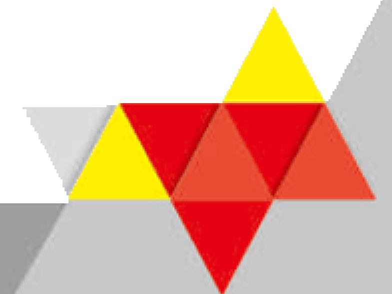




BUBBLE SORT

An Animated Example

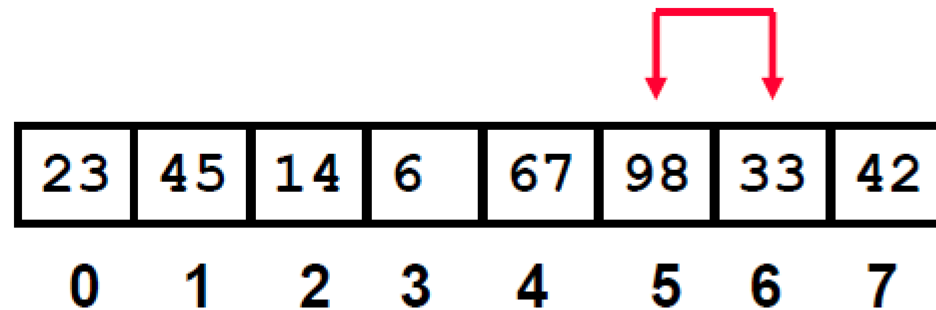


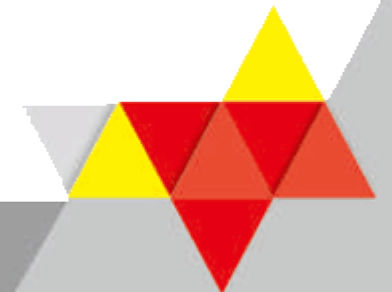


An Animated Example

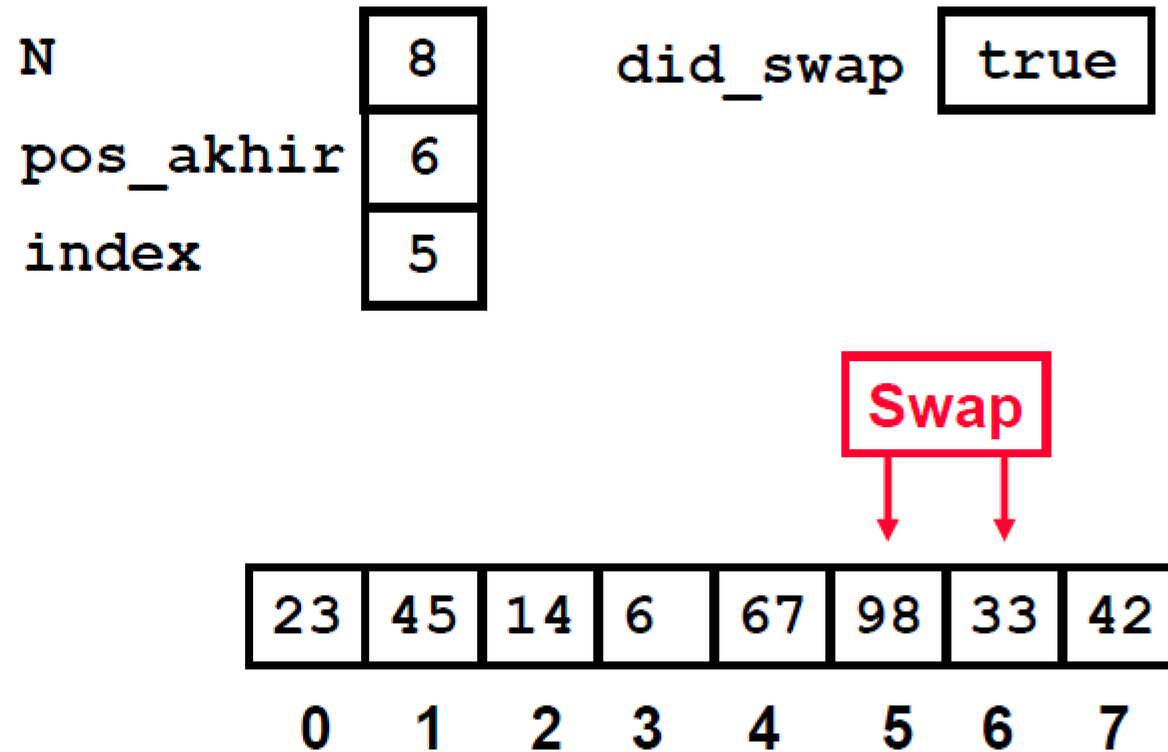
N	8
pos_akhir	6
index	5

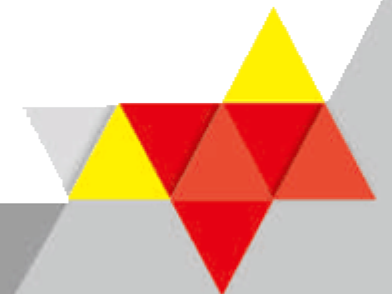
did_swap	true



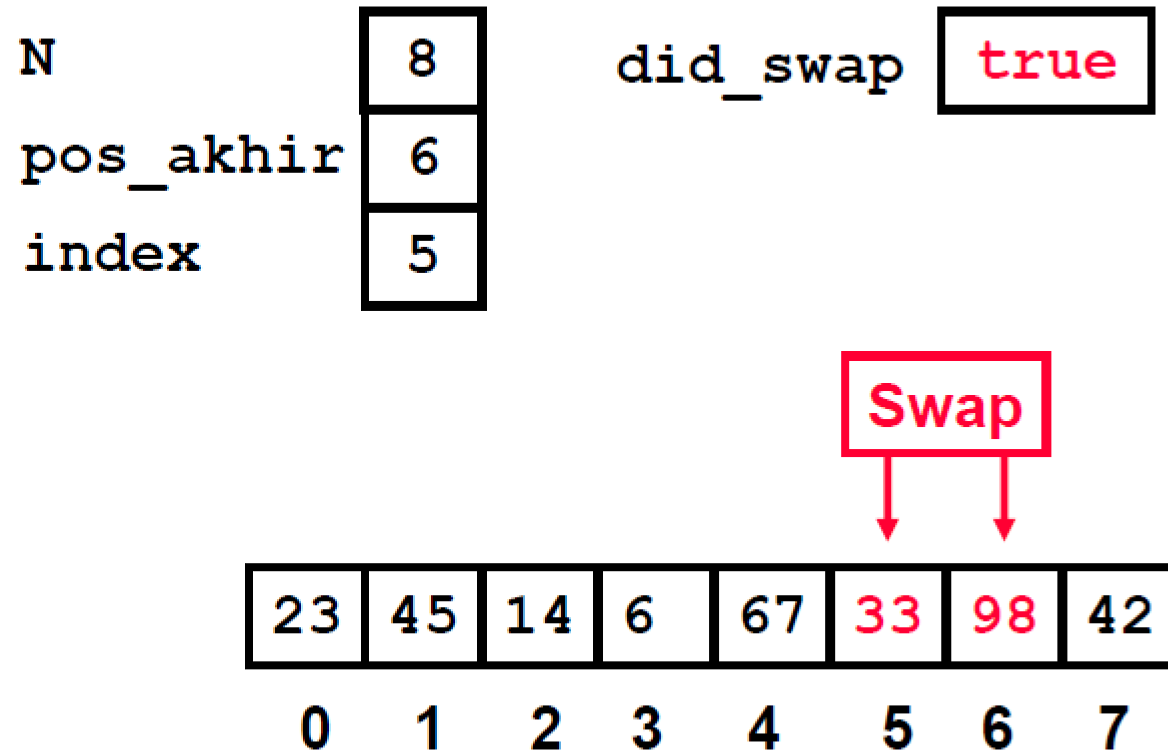


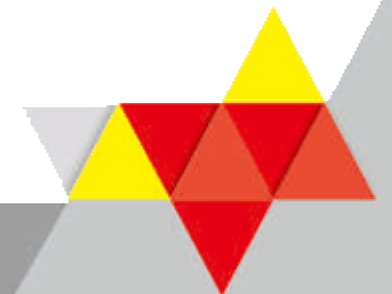
An Animated Example





An Animated Example



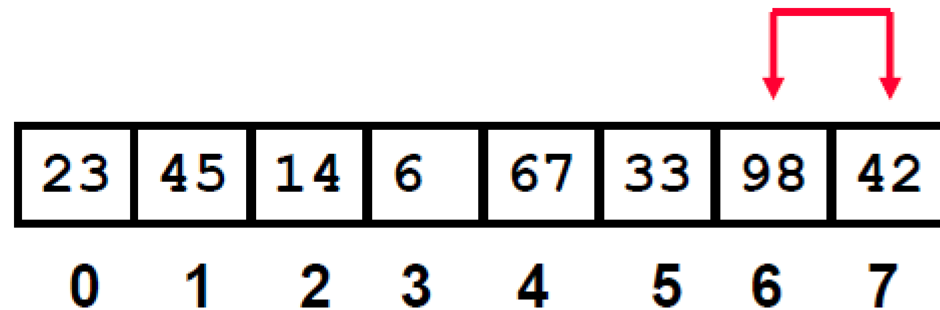


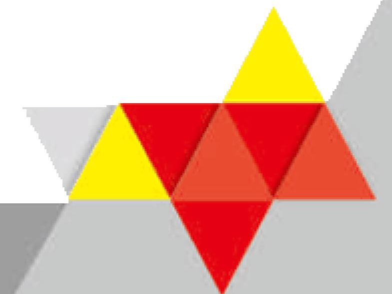
BUBBLE SORT

An Animated Example

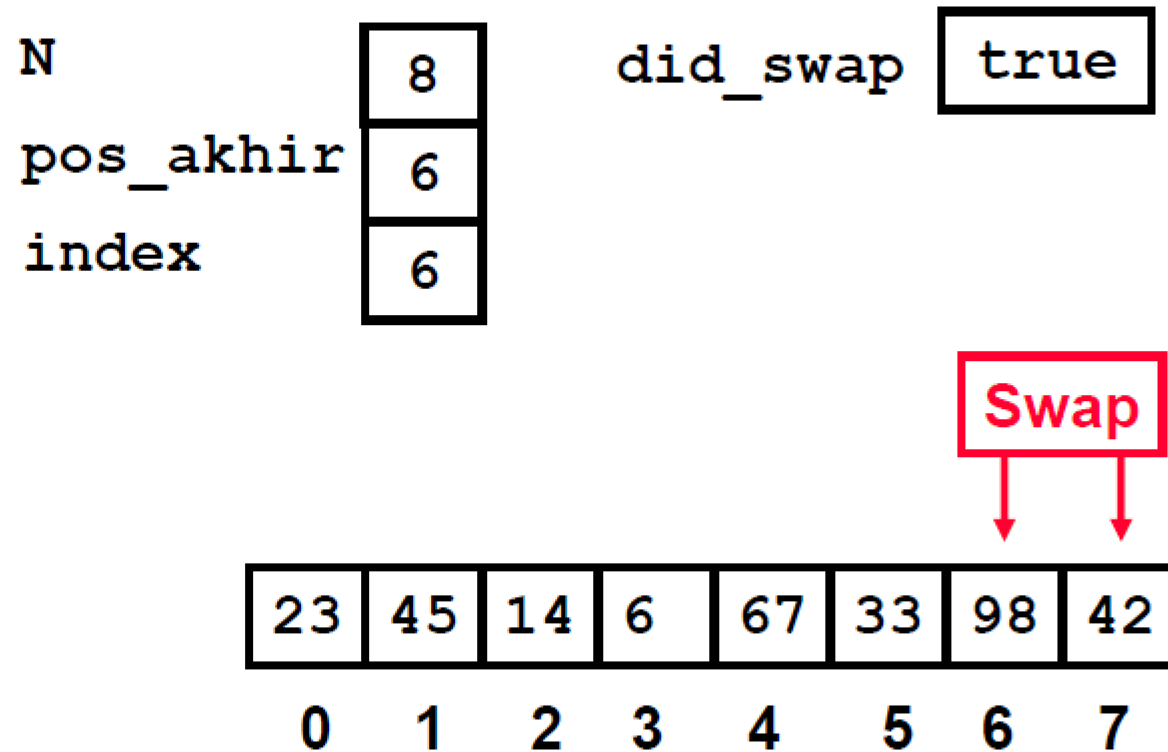
N	8
pos_akhir	6
index	6

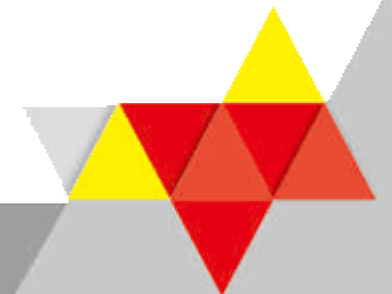
did_swap: true





An Animated Example





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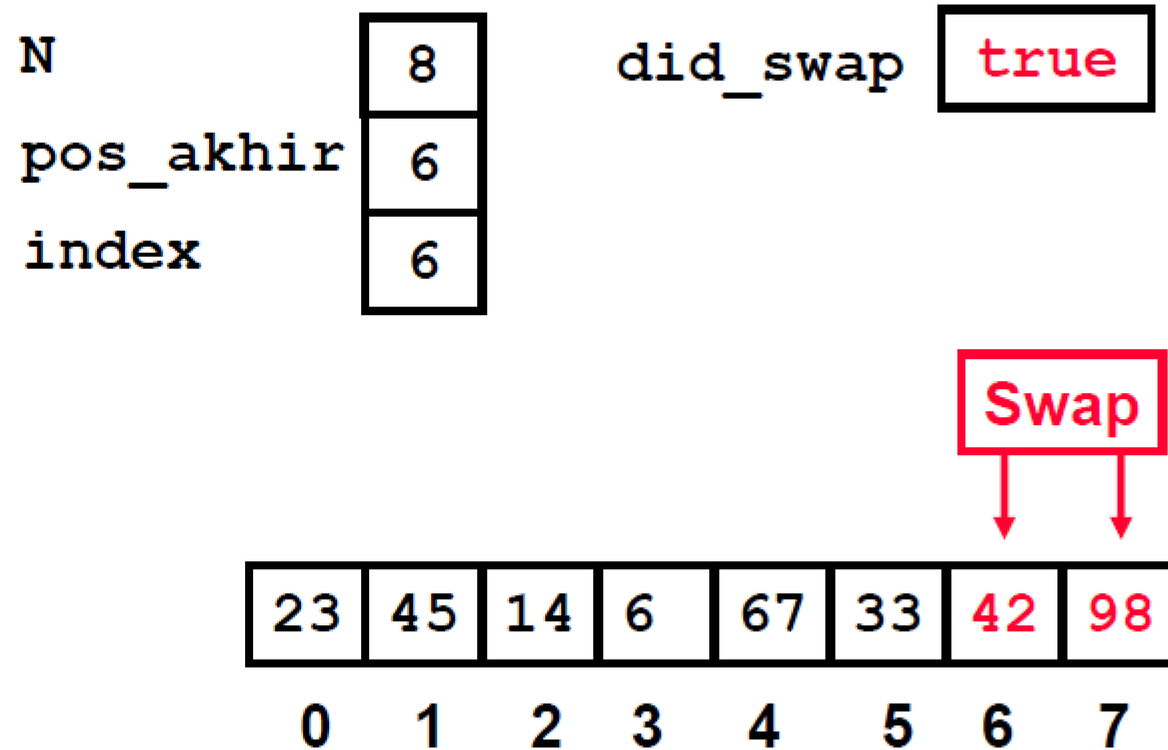
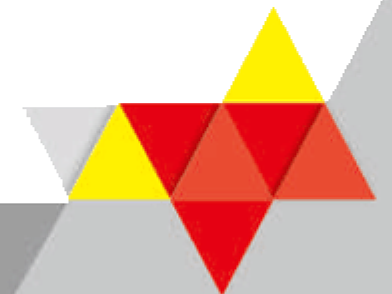
BUBBLE SORT

An Animated Example





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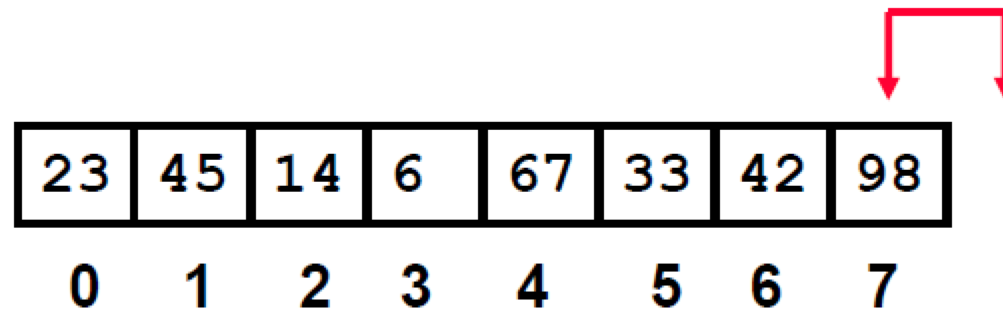
BUBBLE SORT

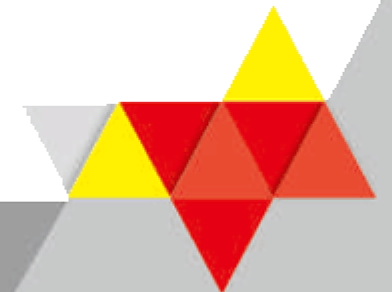
After First Pass of Outer Loop

N	8
pos_akhir	6
index	7

did_swap: true

Finished first "Bubble Up"





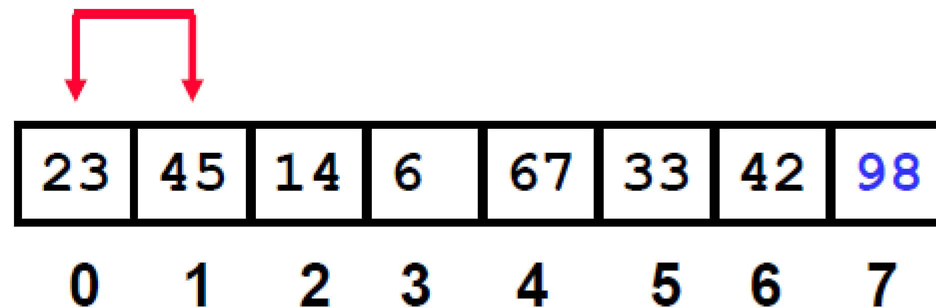
The Second “Bubble Up”

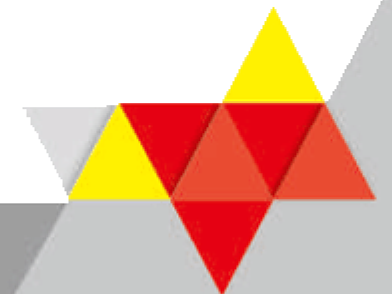
N 8

pos_akhir 5

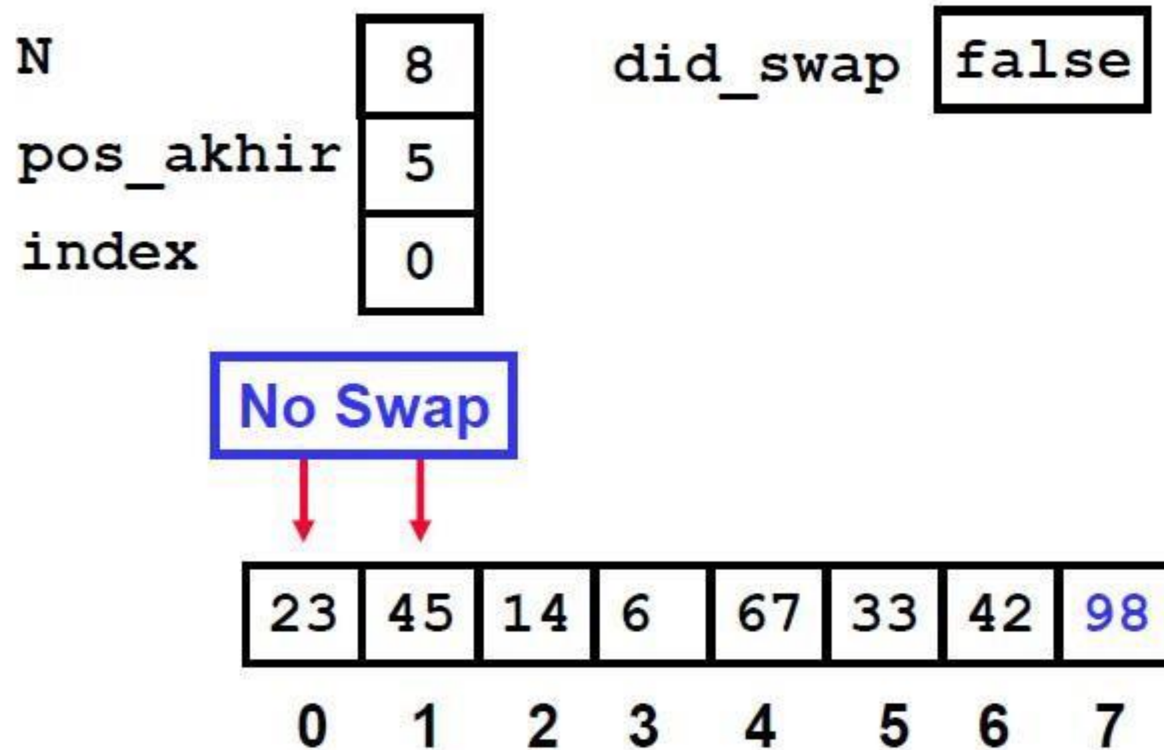
index 0

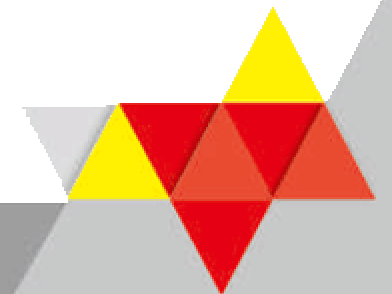
did_swap false





The Second "Bubble Up"

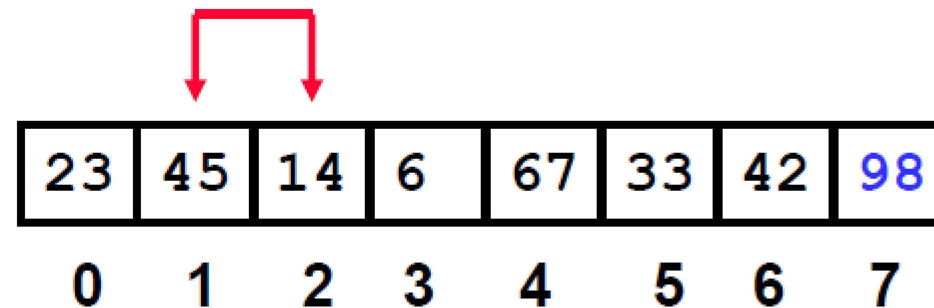


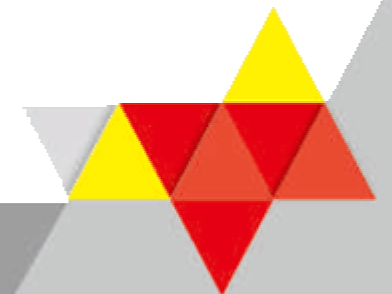


The Second “Bubble Up”

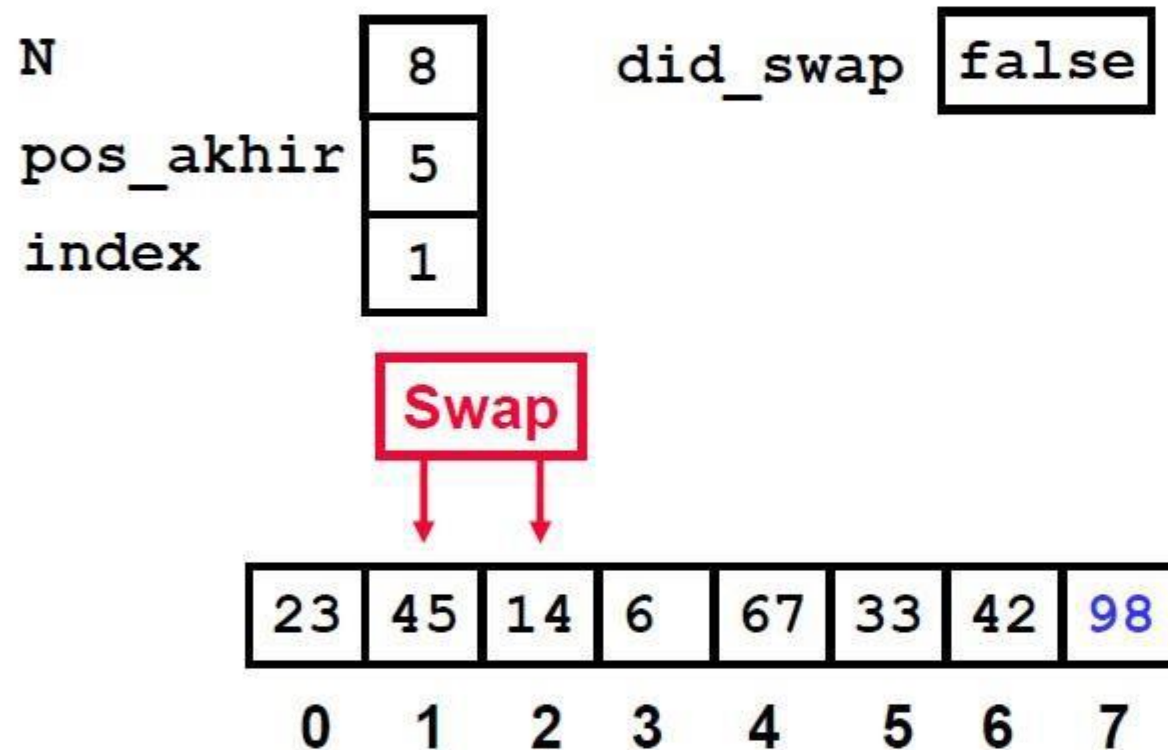
N	8
pos_akhir	5
index	1

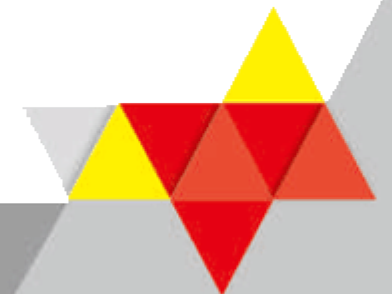
did_swap	false



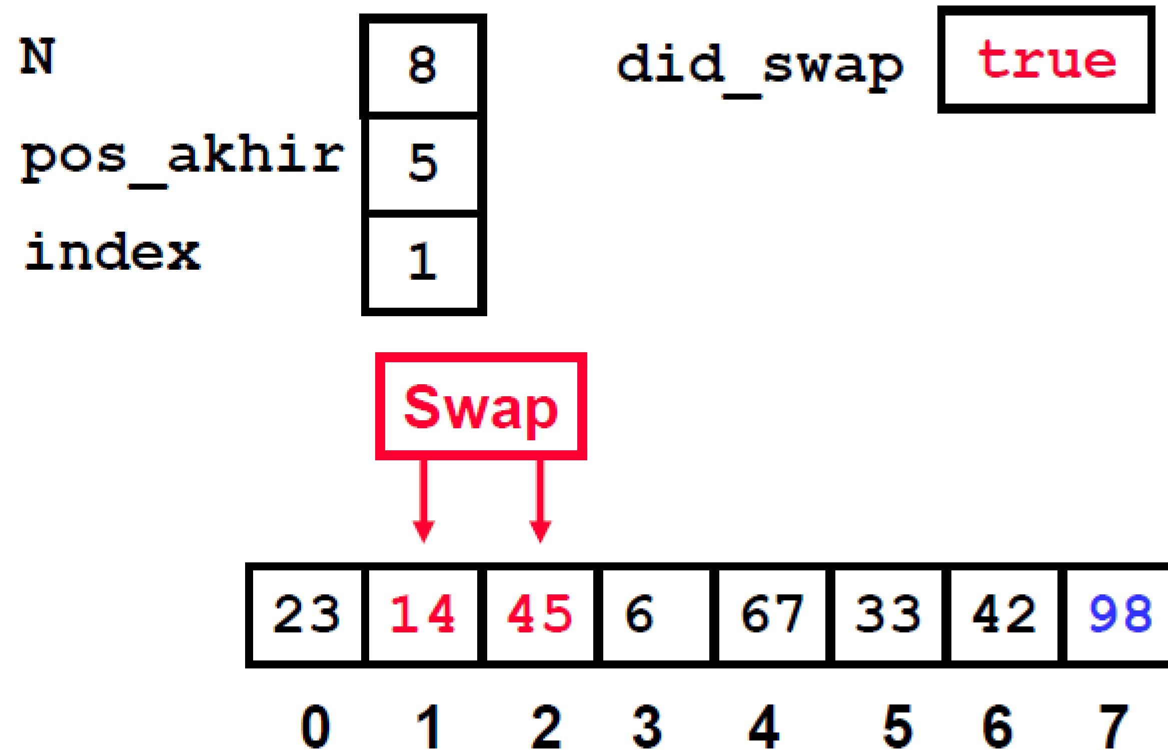


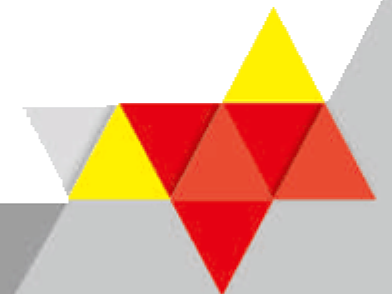
The Second "Bubble Up"





The Second "Bubble Up"





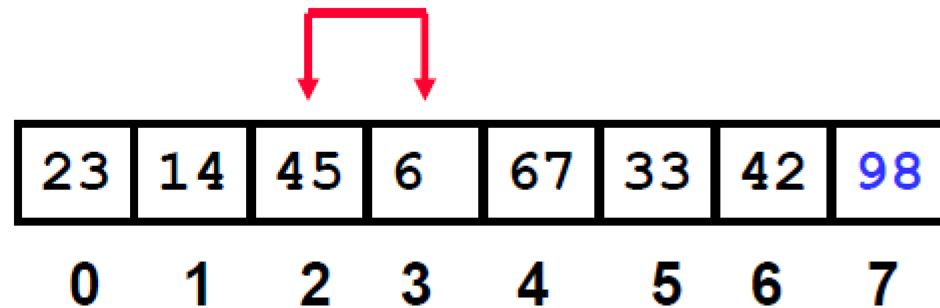
The Second "Bubble Up"

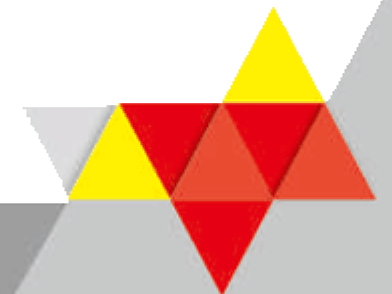
N 8

pos_akhir 5

index 2

did_swap true





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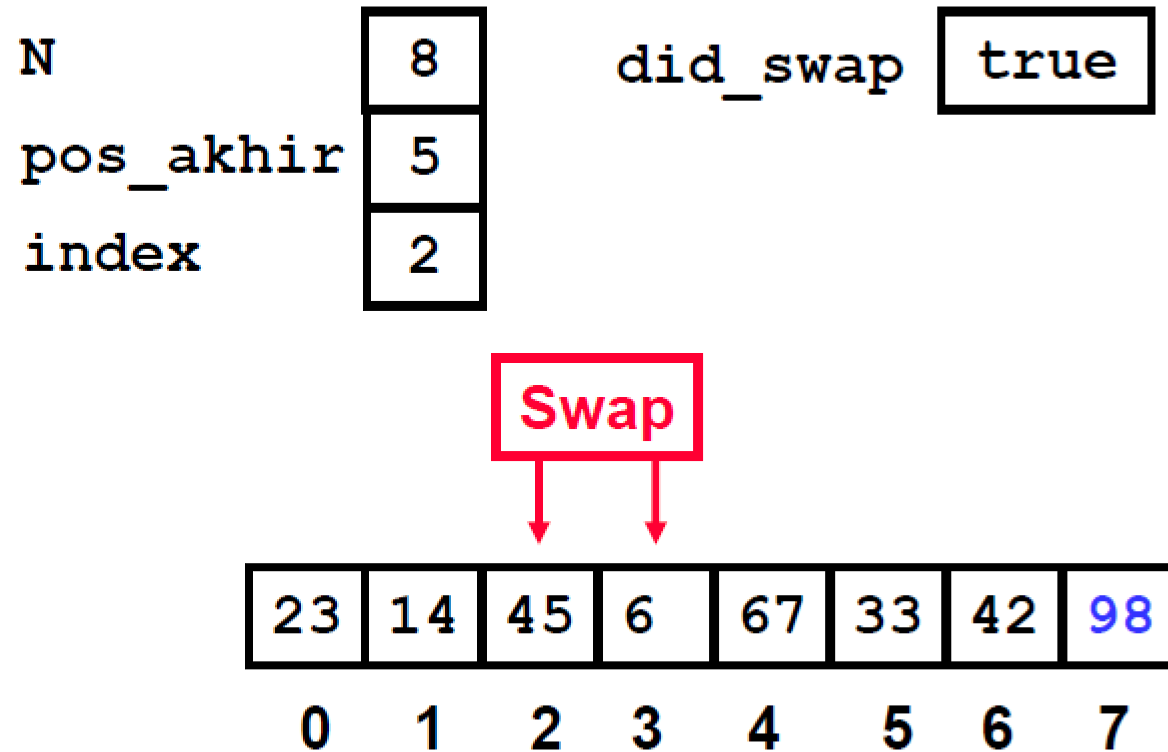
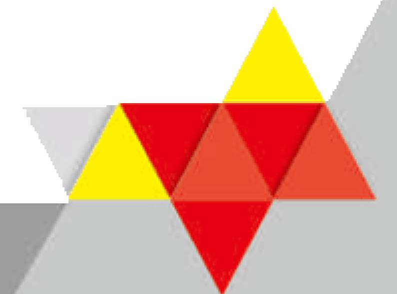
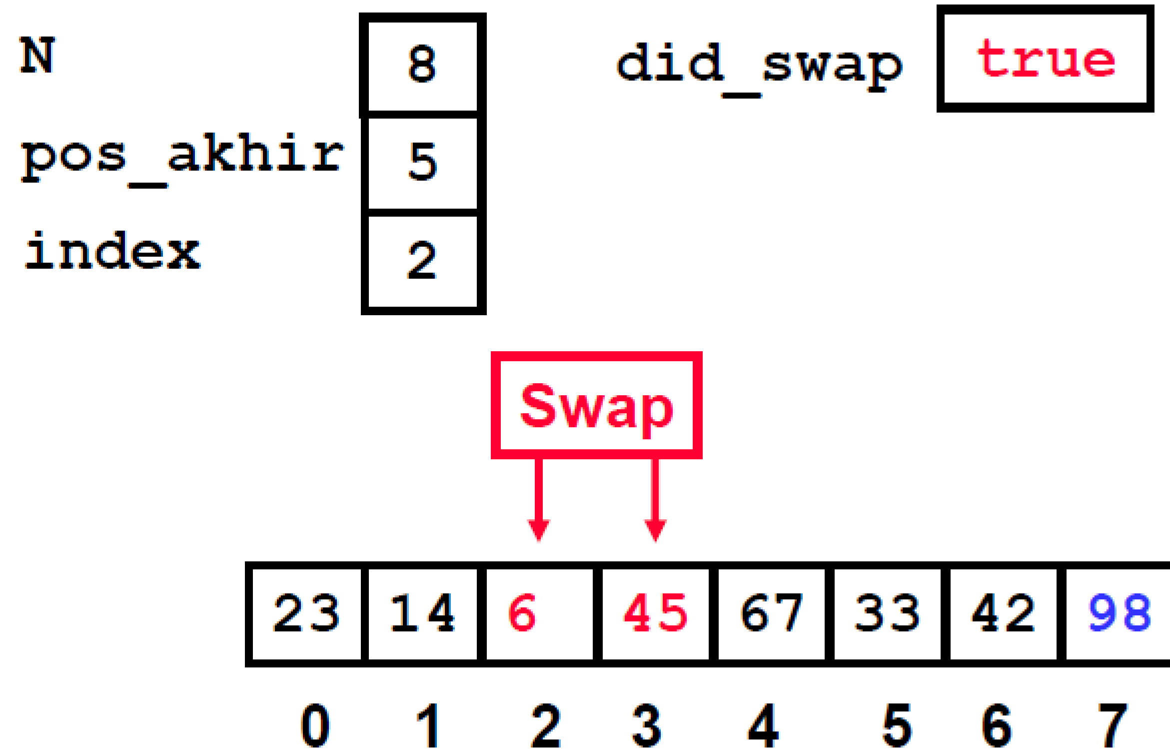
BUBBLE SORT

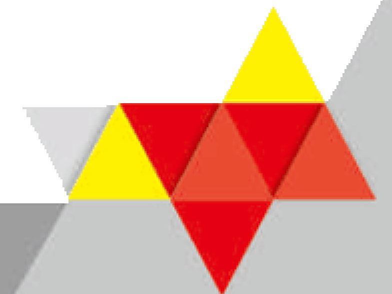
The Second "Bubble Up"





The Second "Bubble Up"

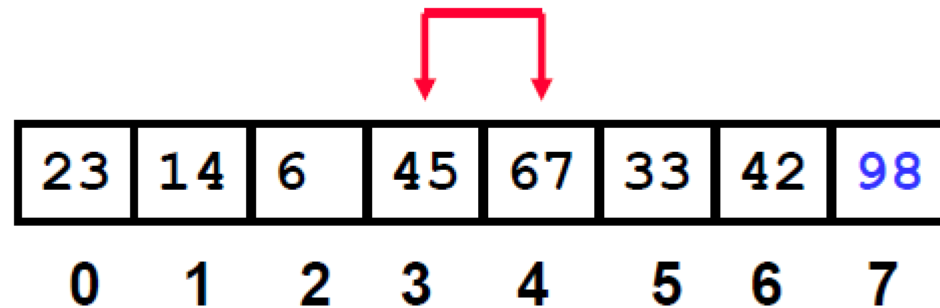


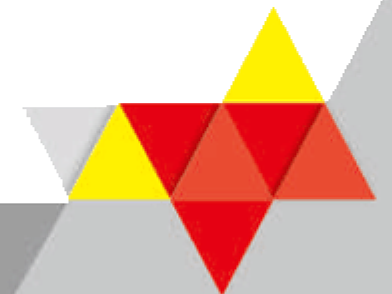


The Second “Bubble Up”

N	8
pos_akhir	5
index	3

did_swap	true





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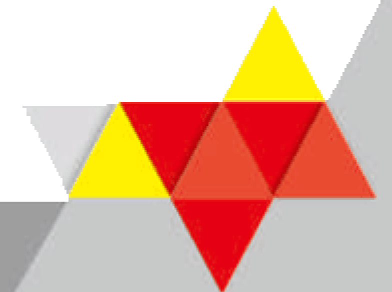
The Second “Bubble Up”

N	8
pos_akhir	5
index	3

did_swap: true

No Swap

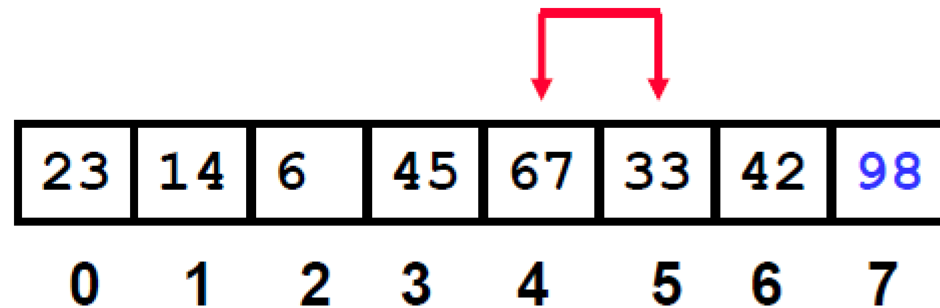
23	14	6	45	67	33	42	98
0	1	2	3	4	5	6	7

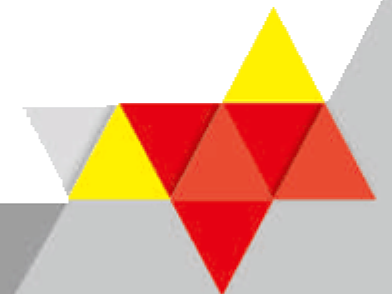


The Second “Bubble Up”

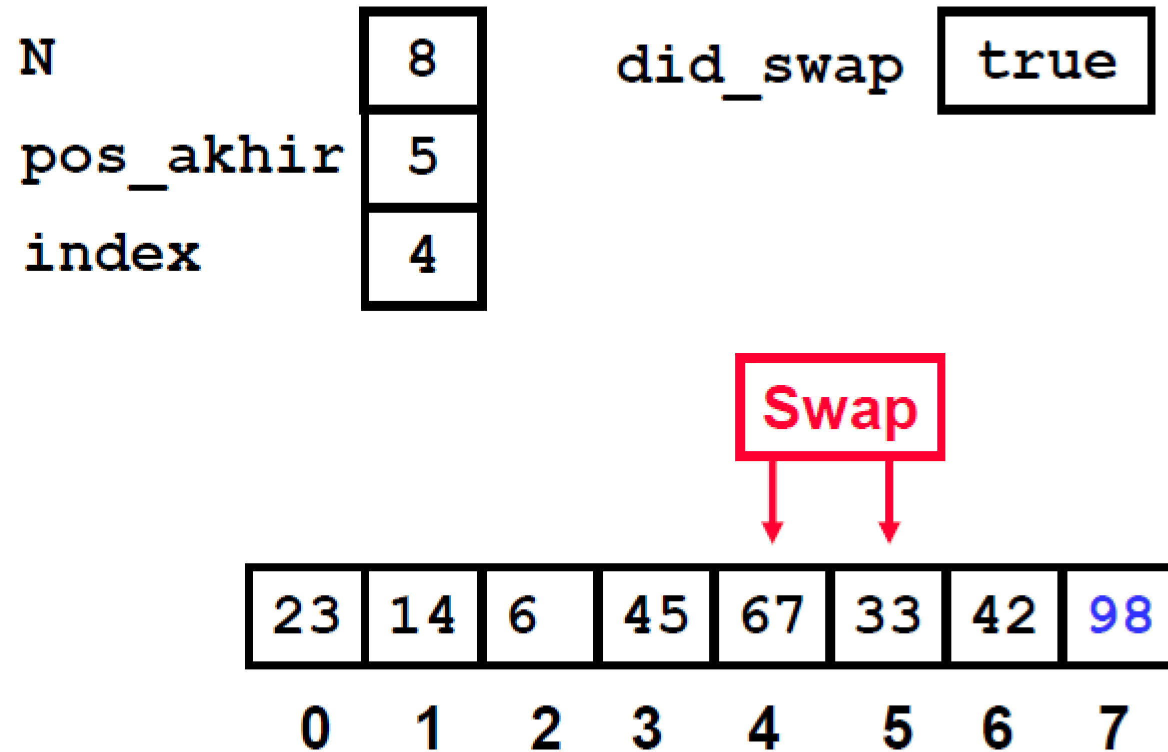
N	8
pos_akhir	5
index	4

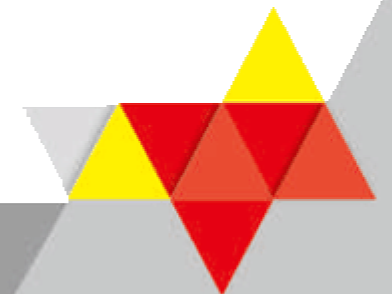
did_swap: true





The Second “Bubble Up”





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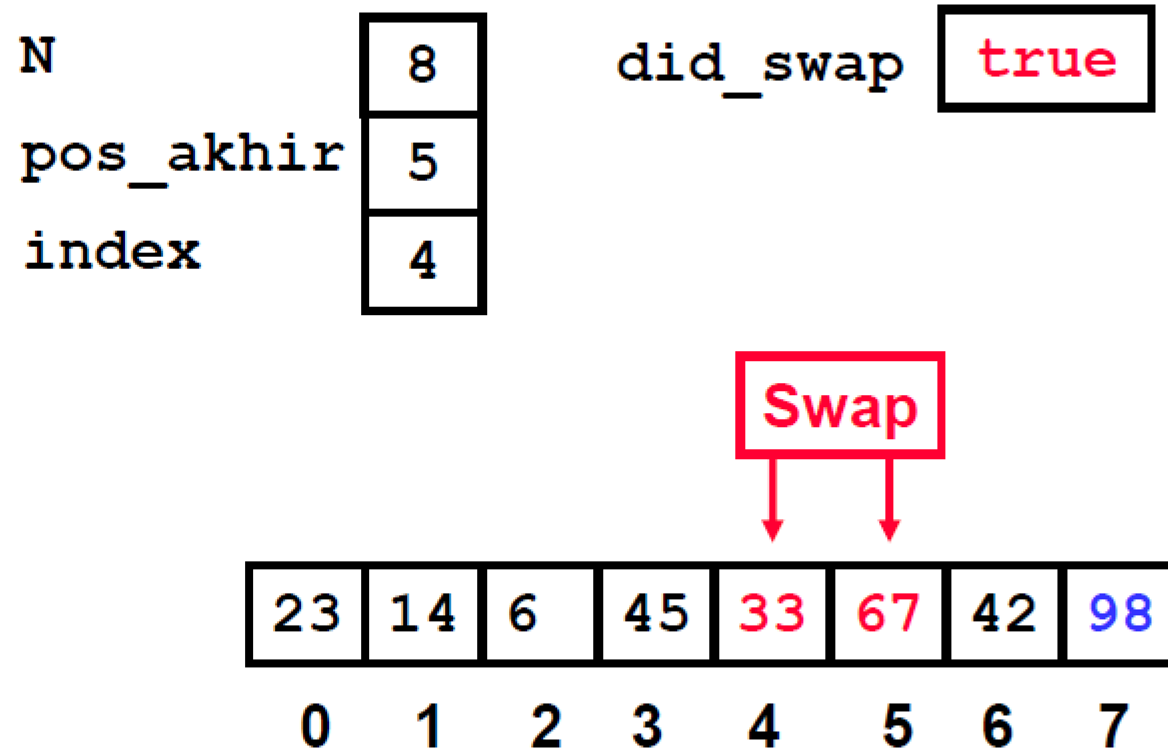
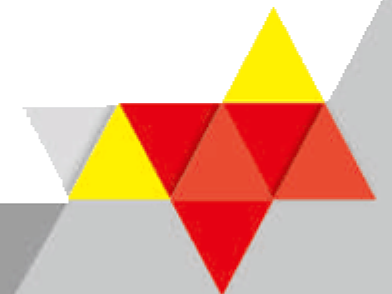
BUBBLE SORT

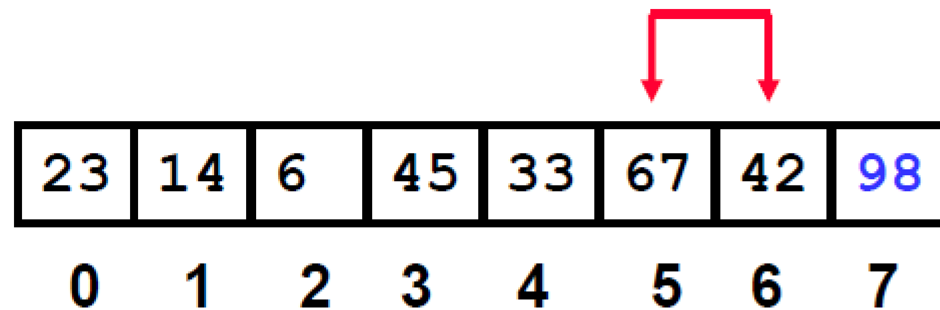
The Second "Bubble Up"

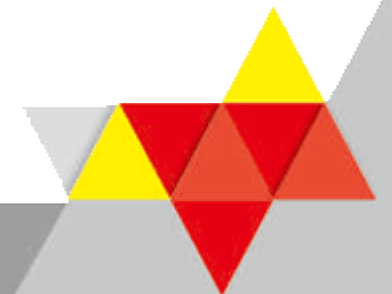




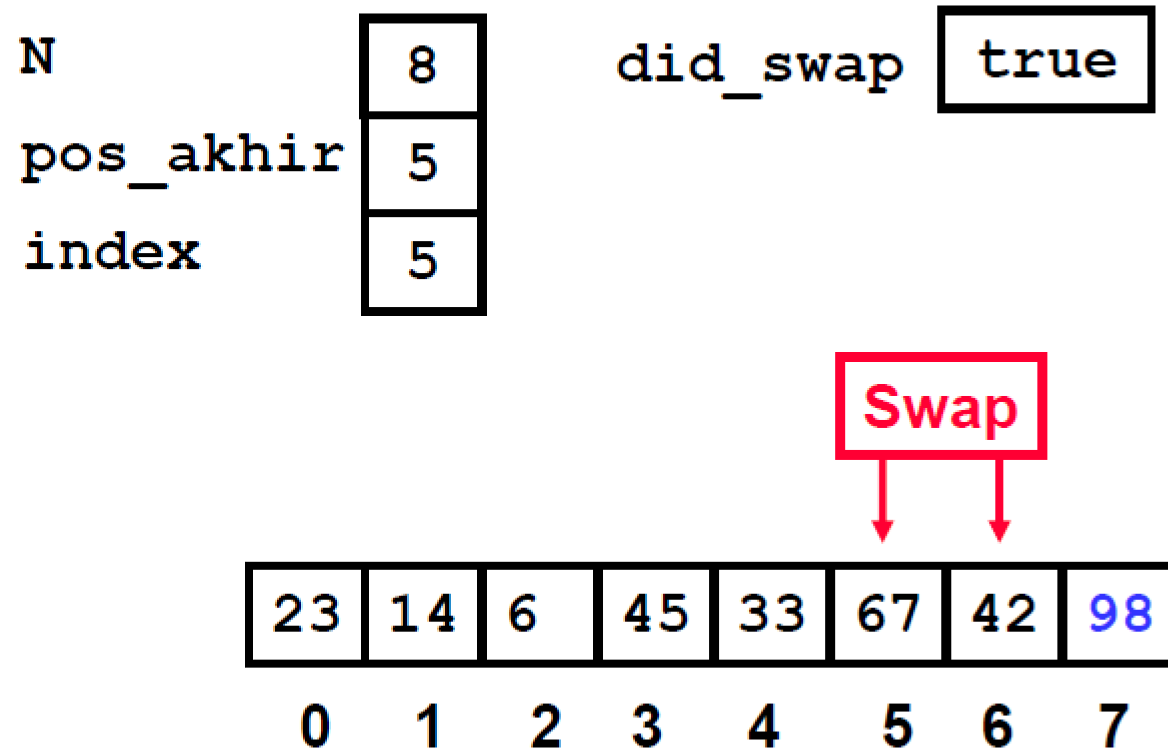
The Second “Bubble Up”

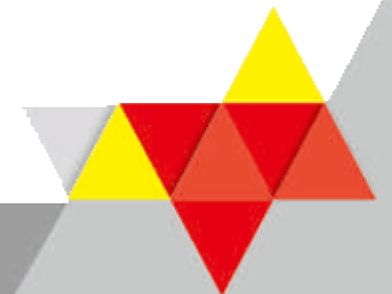
```
N            8
pos_akhir    5
index        5

did_swap   true
```





The Second “Bubble Up”



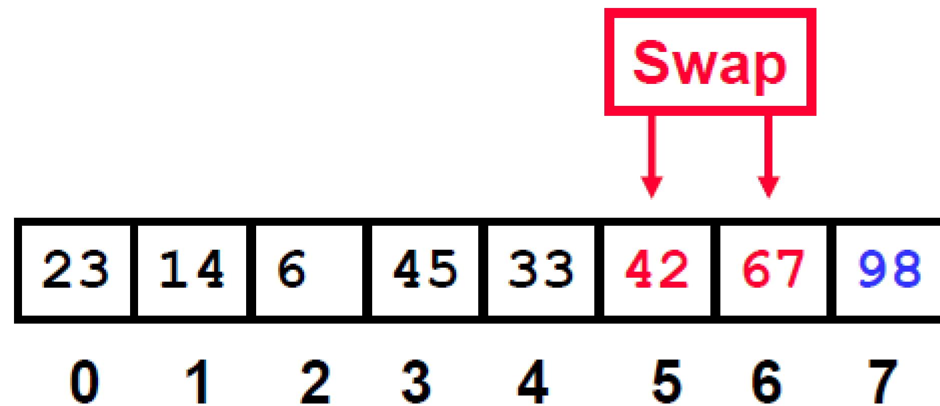


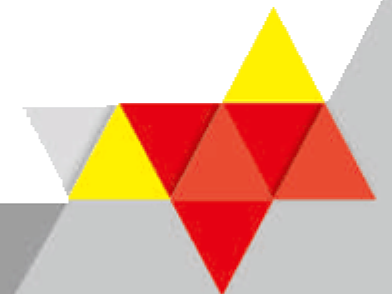
BUBBLE SORT

The Second “Bubble Up”

N	8
pos_akhir	5
index	5

did_swap: true





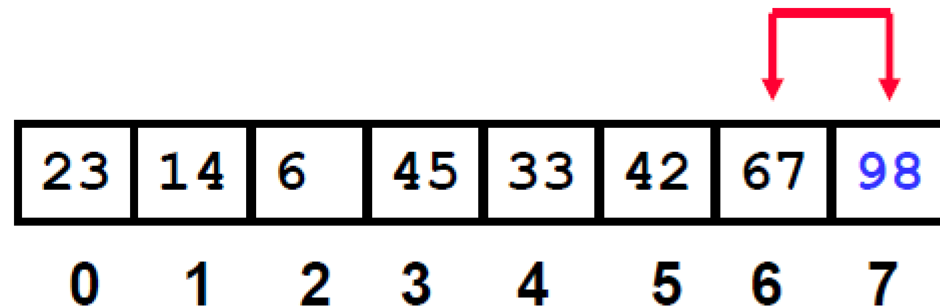
After Second Pass of Outer Loop

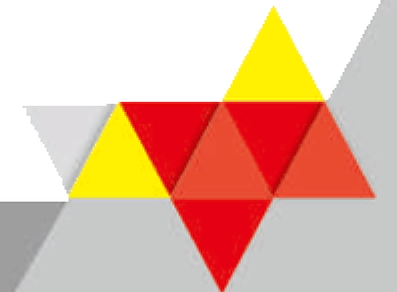
BUBBLE SORT

N	8
pos_akhir	5
index	6

did_swap: true

Finished second "Bubble Up"





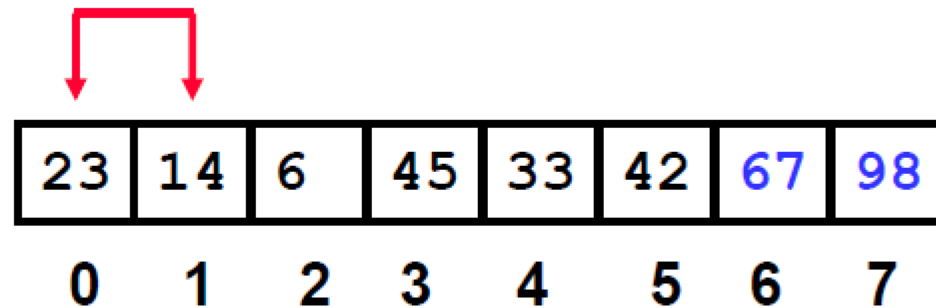
The Third "Bubble Up"

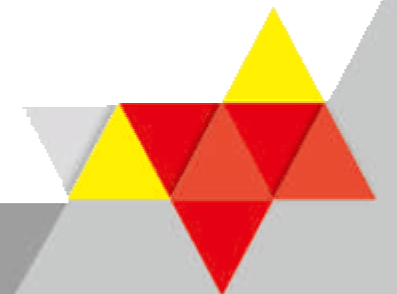
N 8

pos_akhir 4

index 0

did_swap false





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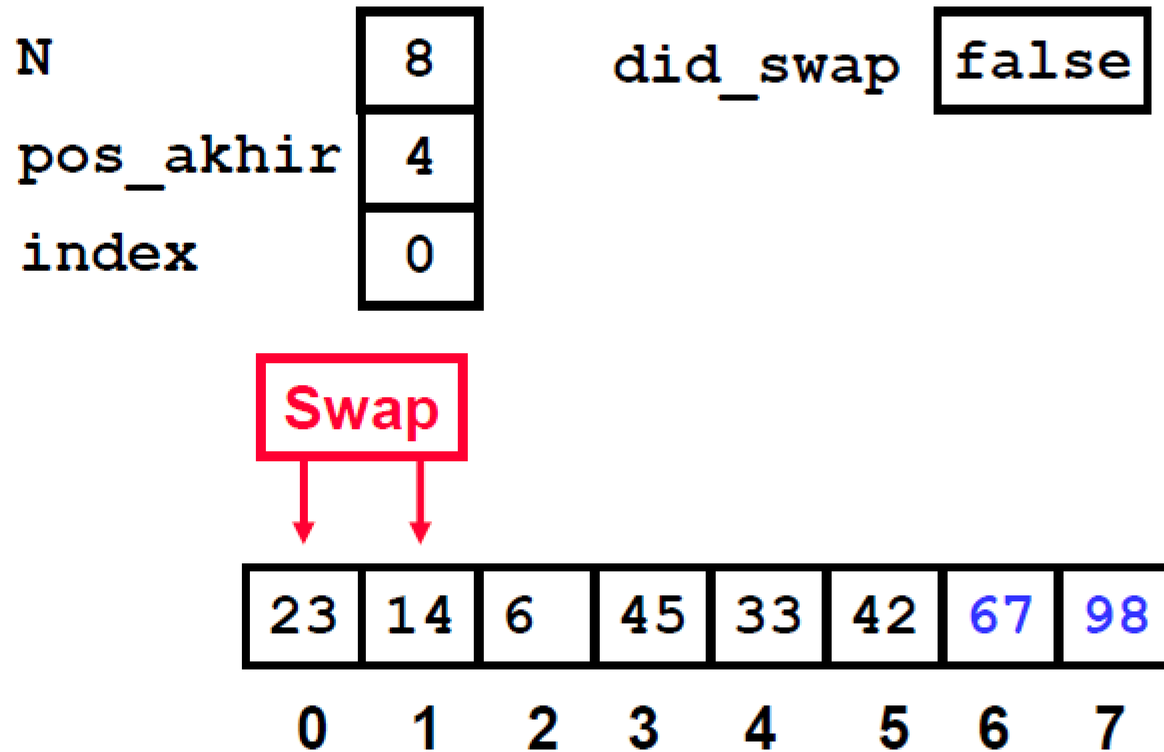
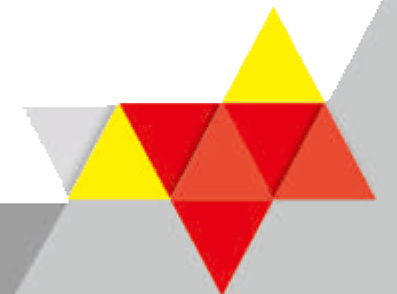
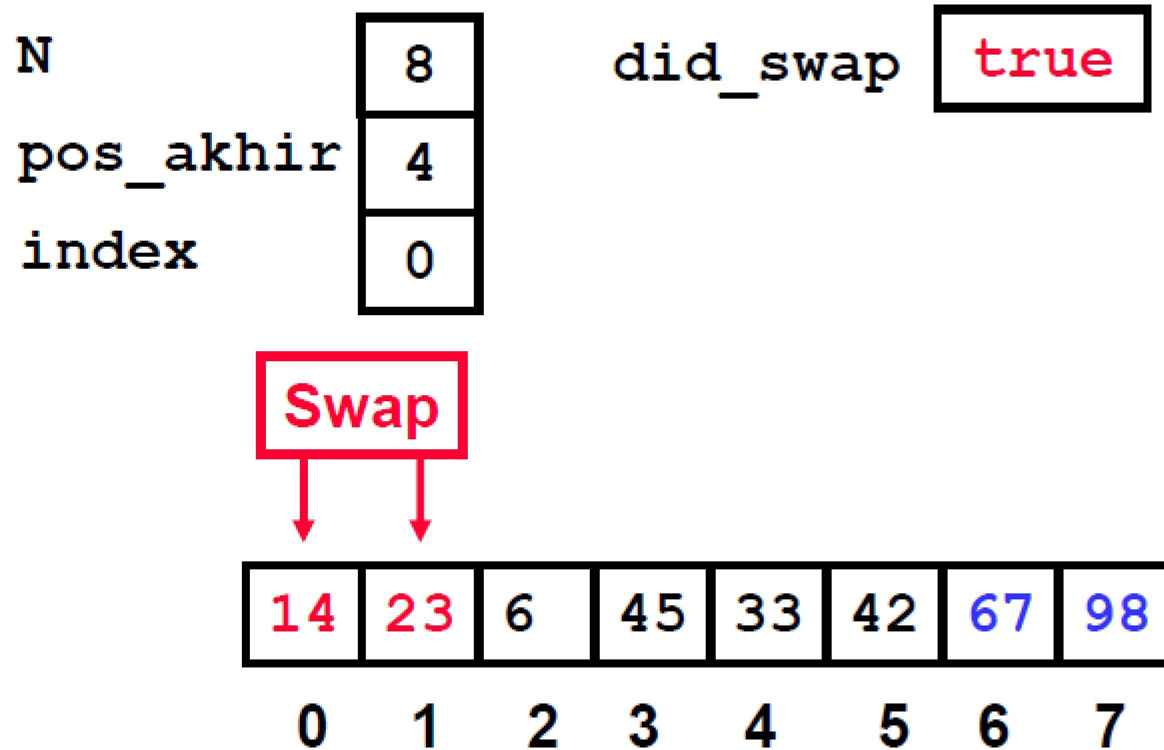
BUBBLE SORT

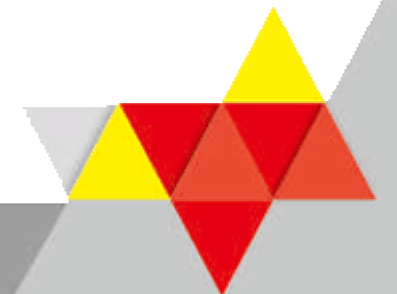
The Third "Bubble Up"





The Third "Bubble Up"

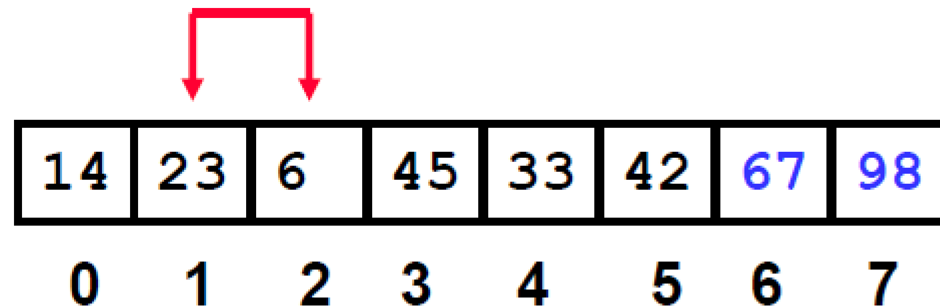


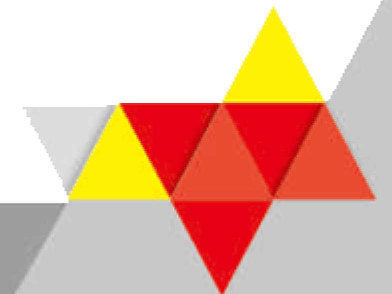


The Third "Bubble Up"

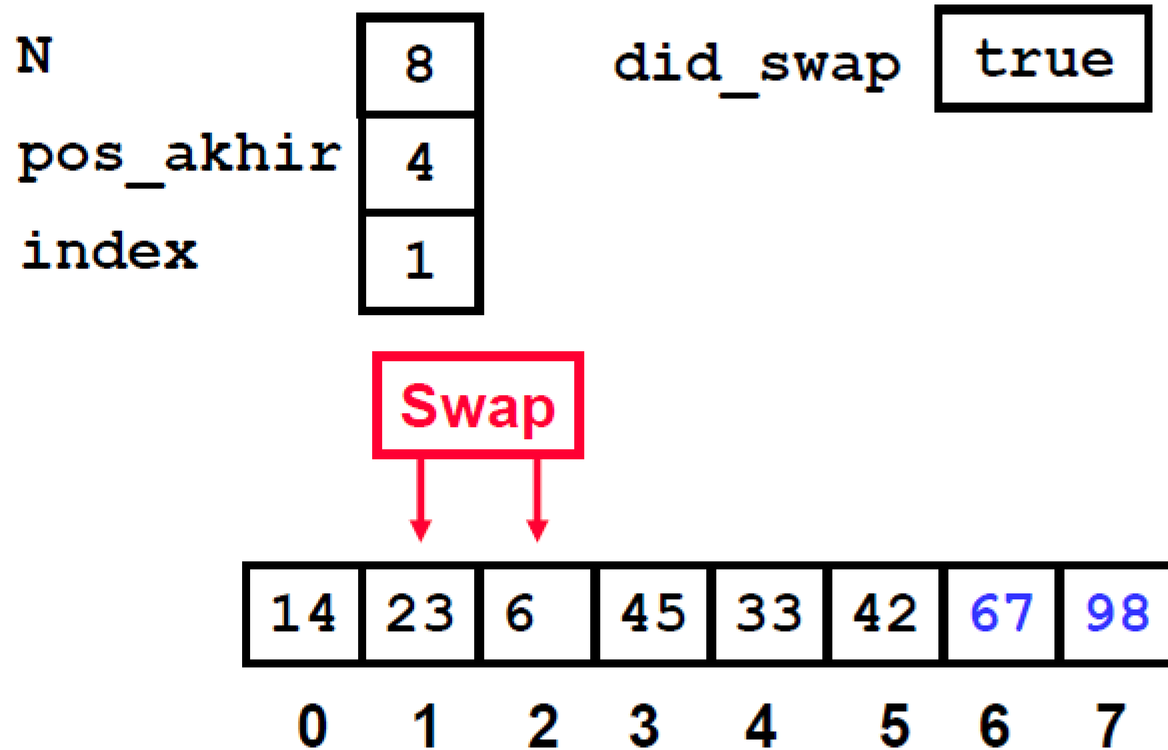
N	8
pos_akhir	4
index	1

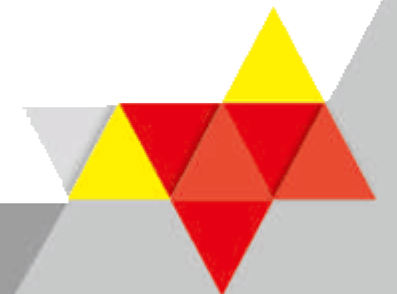
did_swap: true





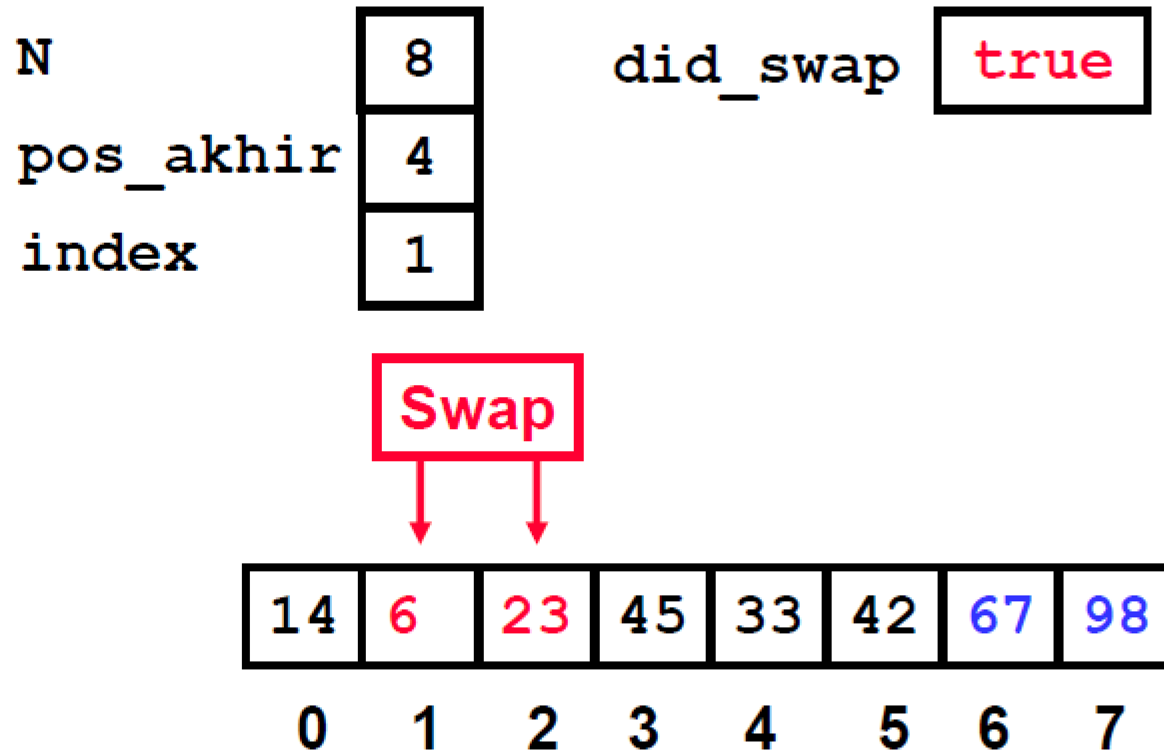
The Third "Bubble Up"

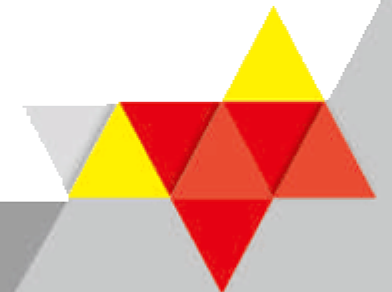




BUBBLE SORT

The Third "Bubble Up"

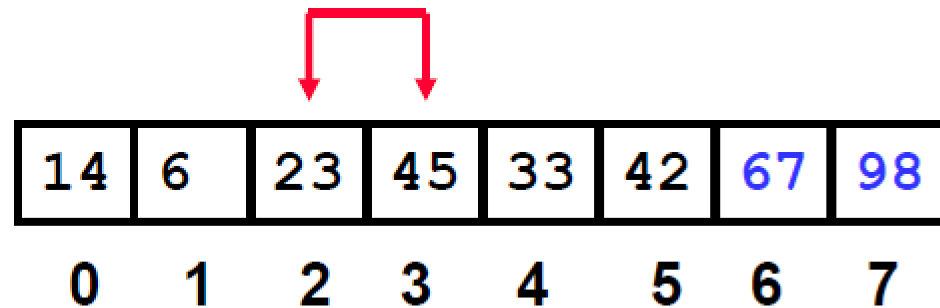


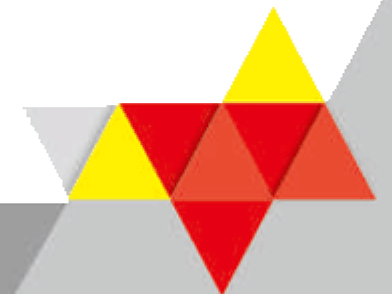


The Third “Bubble Up”

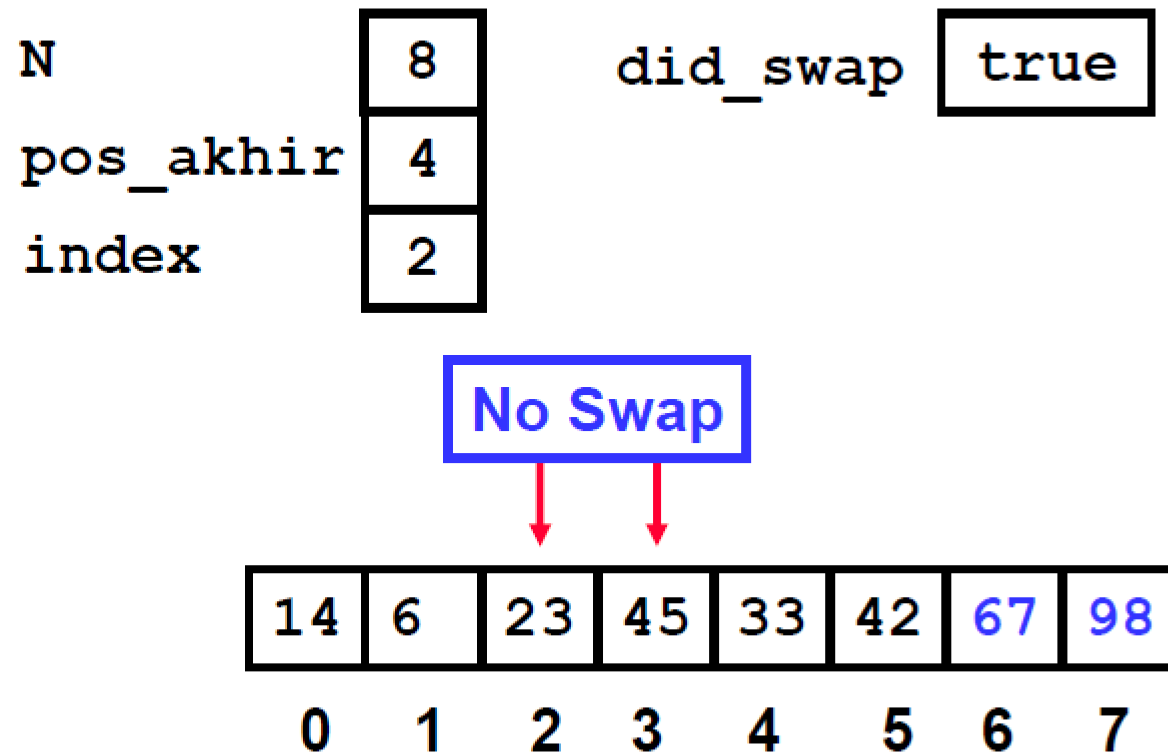
N	8
pos_akhir	4
index	2

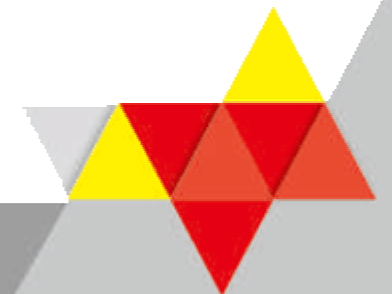
did_swap: true





The Third "Bubble Up"

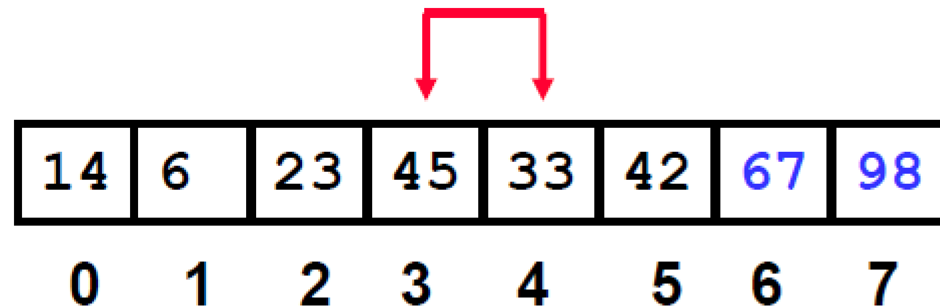


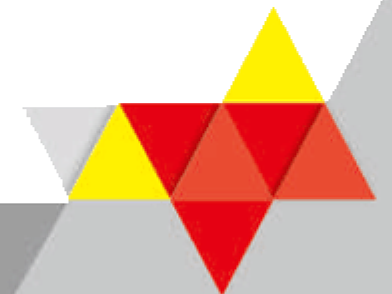


The Third “Bubble Up”

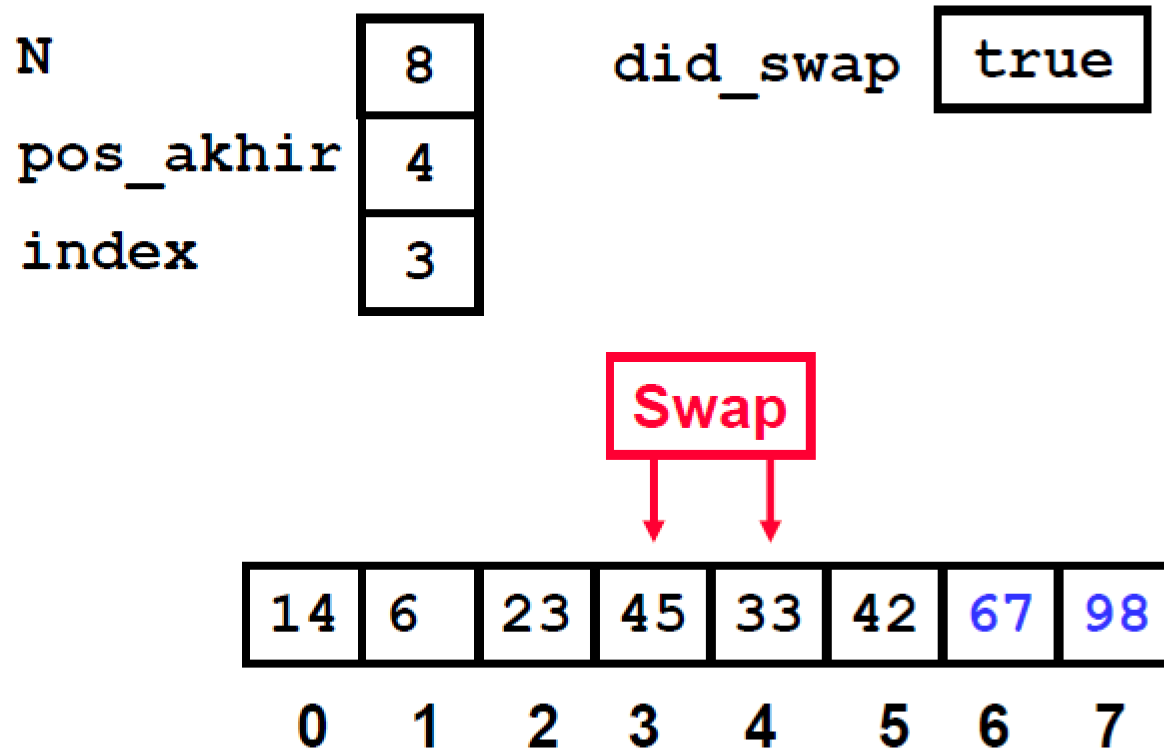
N	8
pos_akhir	4
index	3

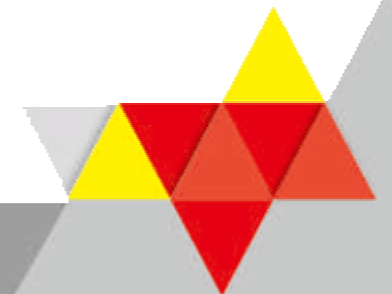
did_swap	true



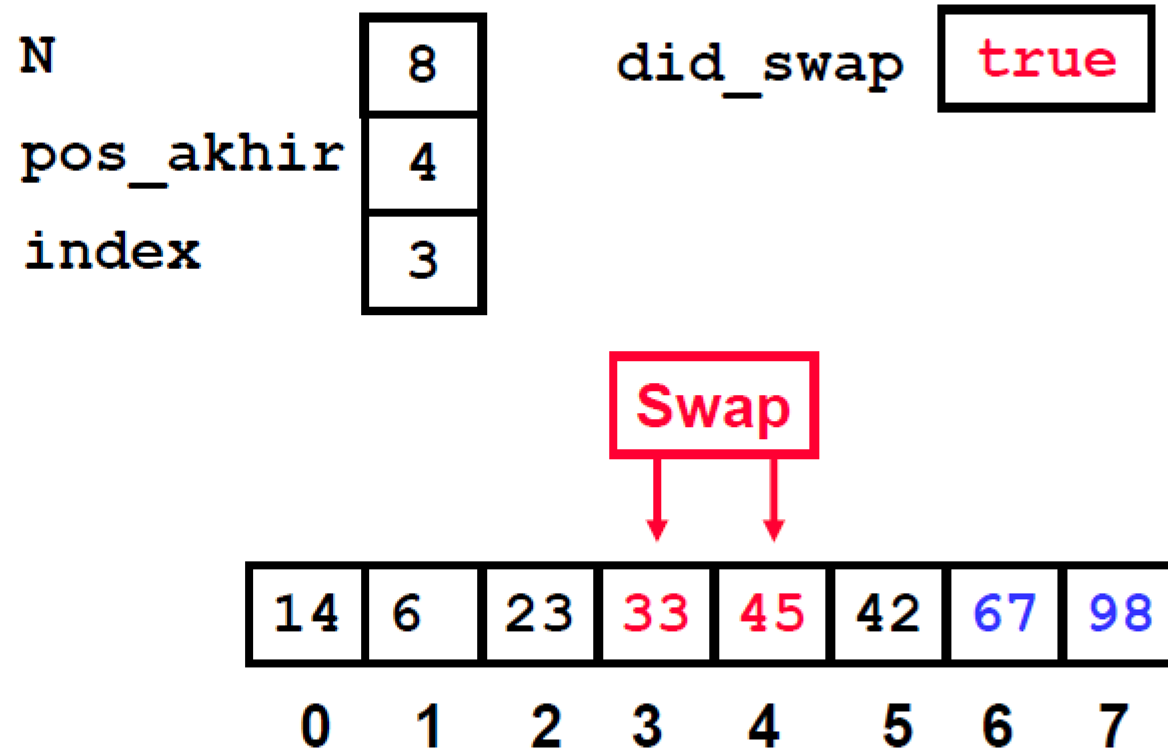


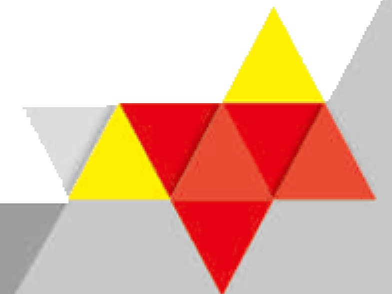
The Third "Bubble Up"





The Third "Bubble Up"

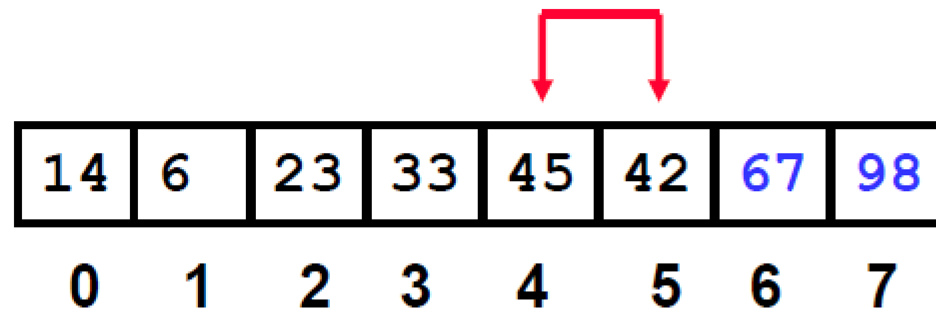


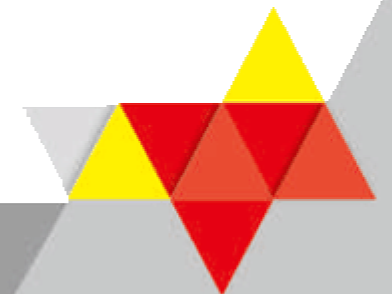


The Third “Bubble Up”

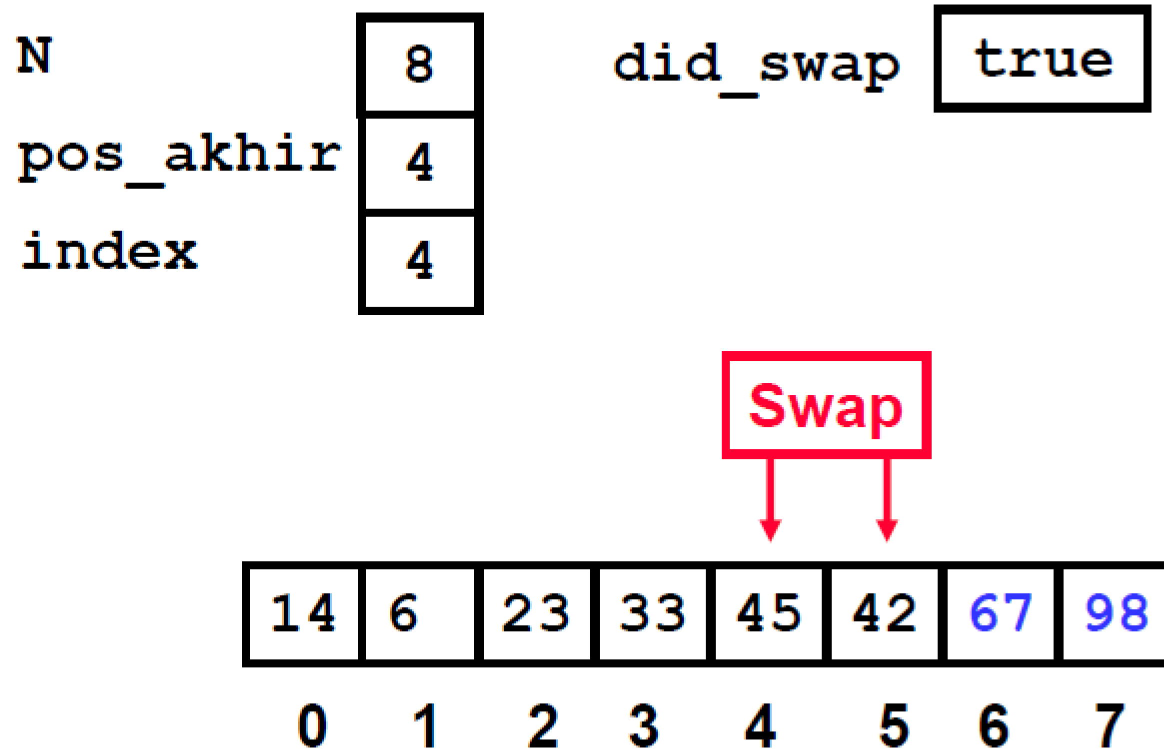
N	8
pos_akhir	4
index	4

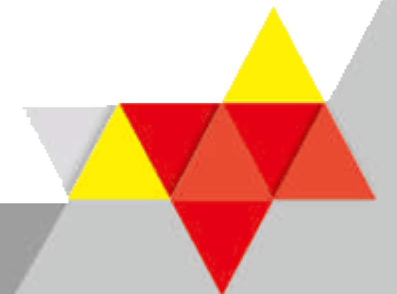
did_swap: true





The Third "Bubble Up"





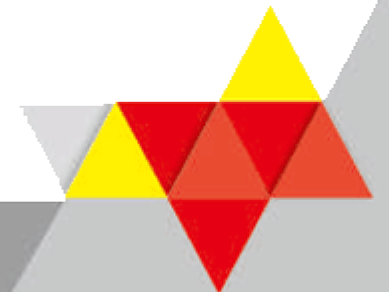
The Third “Bubble Up”

N	8
pos_akhir	4
index	4

did_swap: true

Swap (42 ↔ 45)

14	6	23	33	42	45	67	98
0	1	2	3	4	5	6	7



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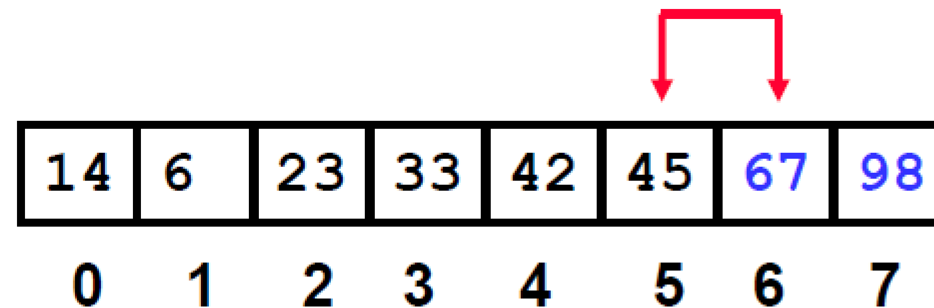
BUBBLE SORT

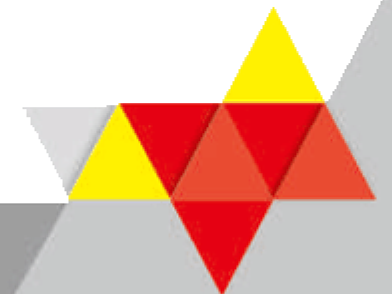
After Third Pass of Outer Loop

N	8
pos_akhir	4
index	5

did_swap: true

Finished third "Bubble Up"

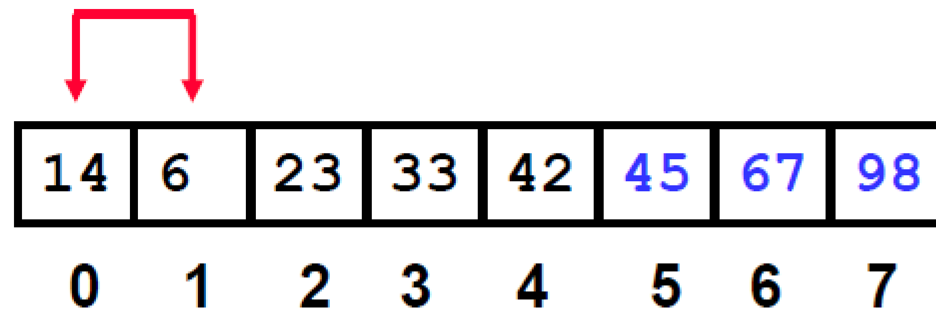


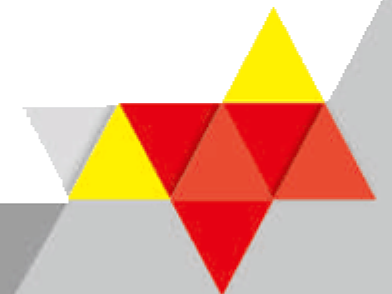


The Fourth “Bubble Up”

N	8
pos_akhir	3
index	0

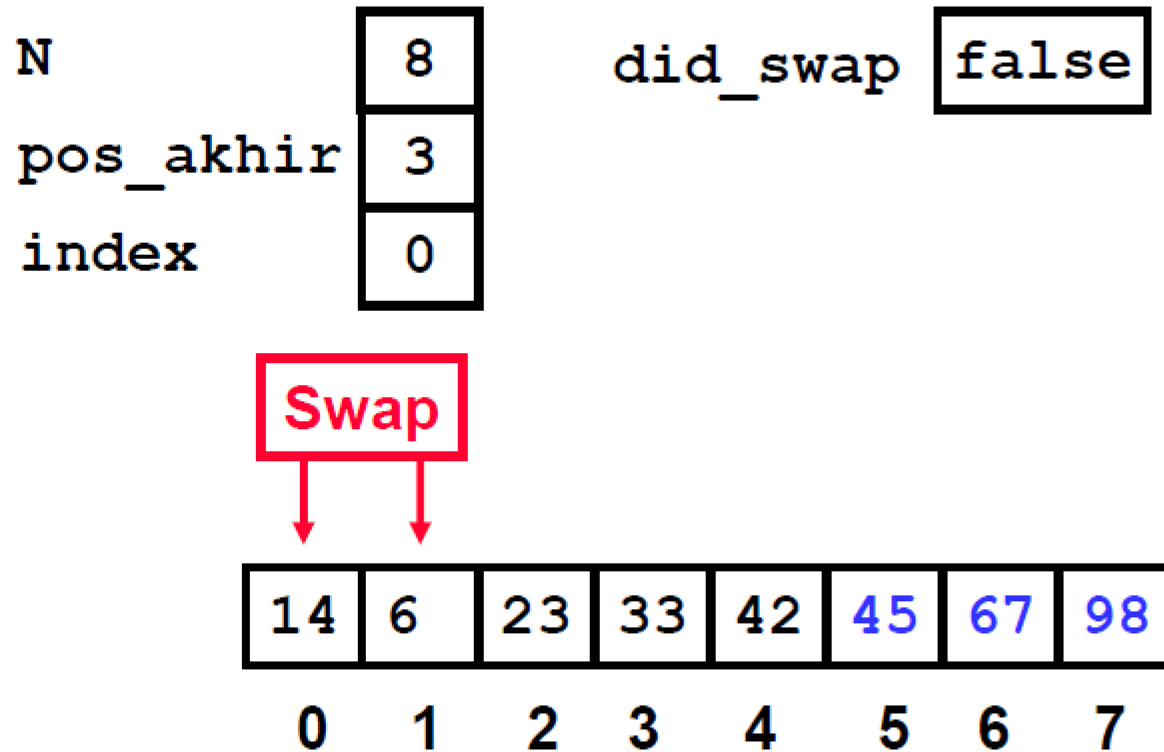
did_swap false

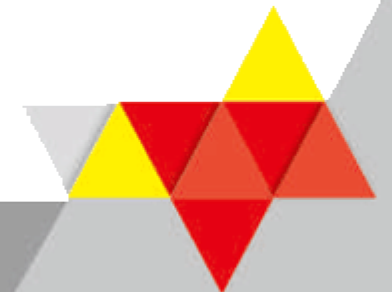




BUBBLE SORT

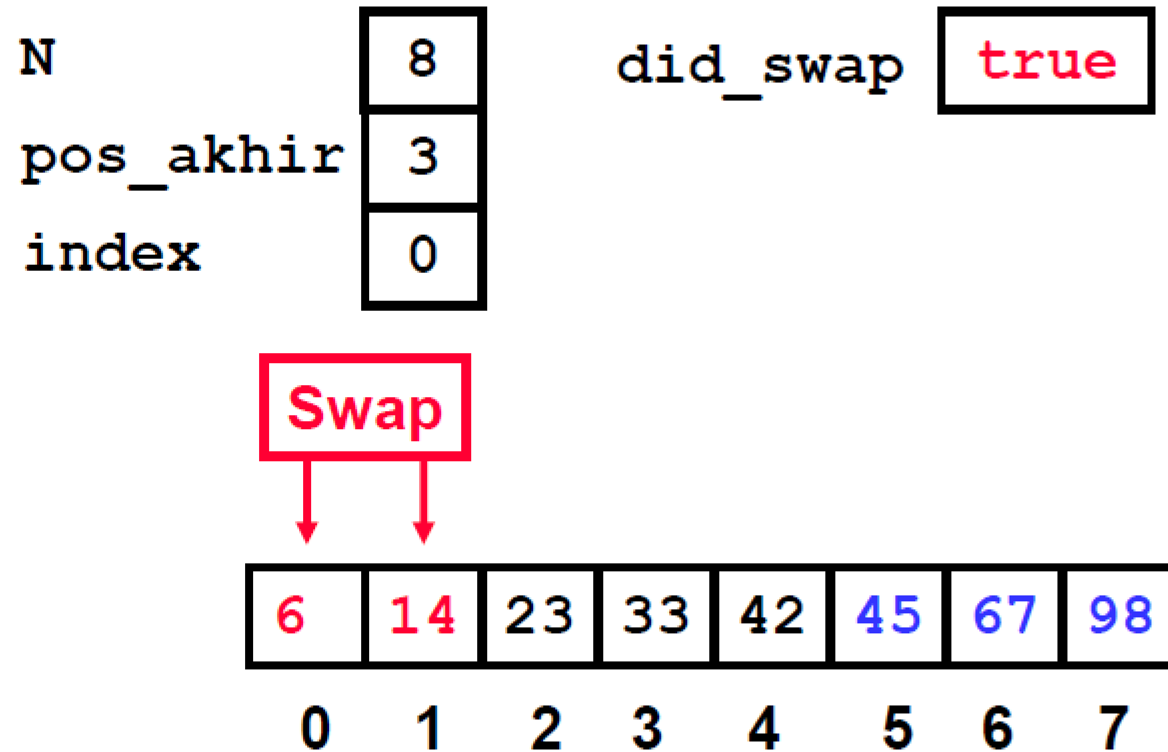
The Fourth “Bubble Up”

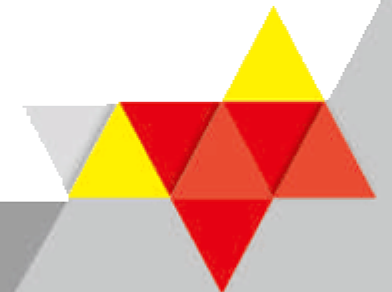


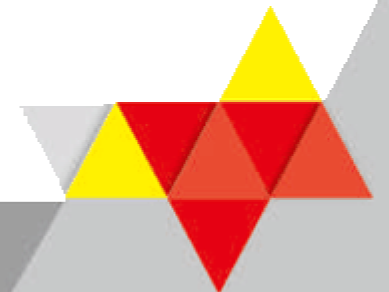


BUBBLE SORT

The Fourth “Bubble Up”





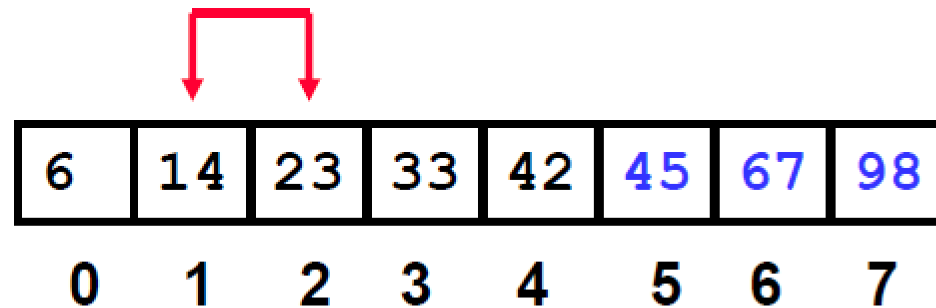


BUBBLE SORT

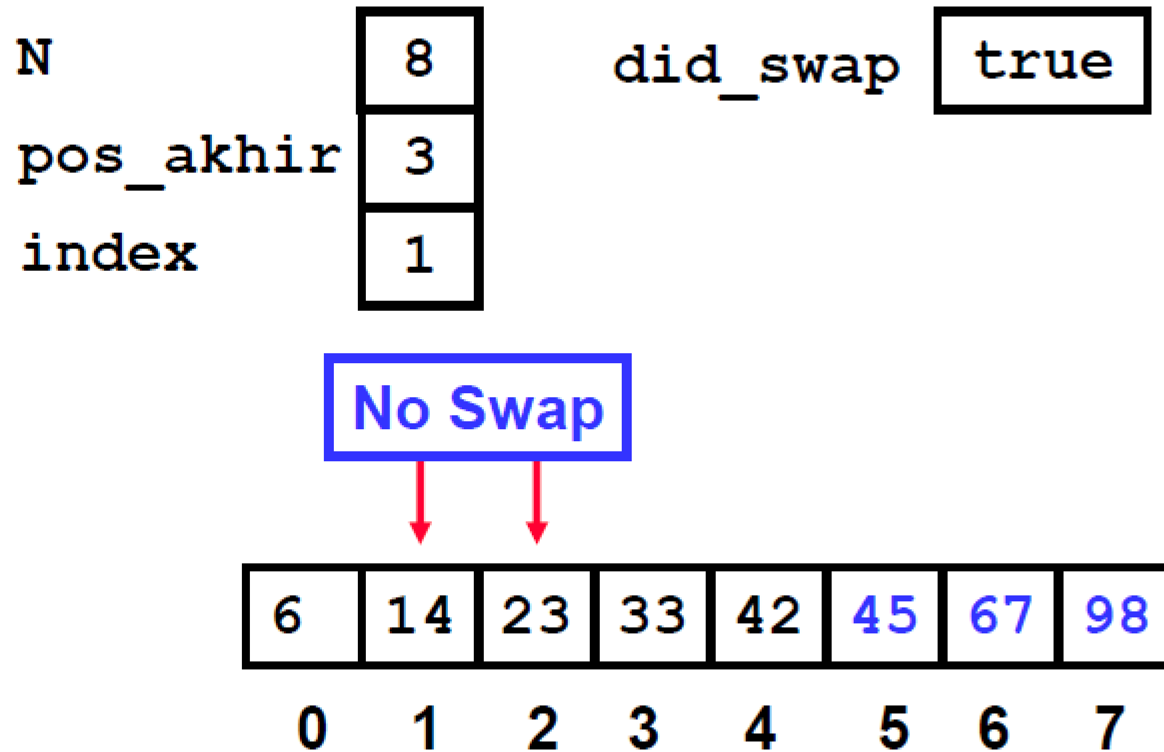
The Fourth "Bubble Up"

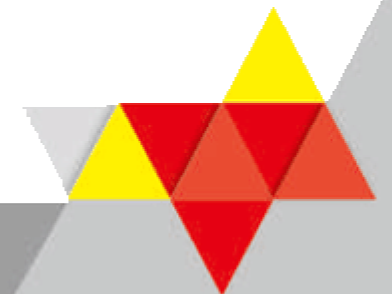
N	8
pos_akhir	3
index	1

did_swap: true



The Fourth “Bubble Up”

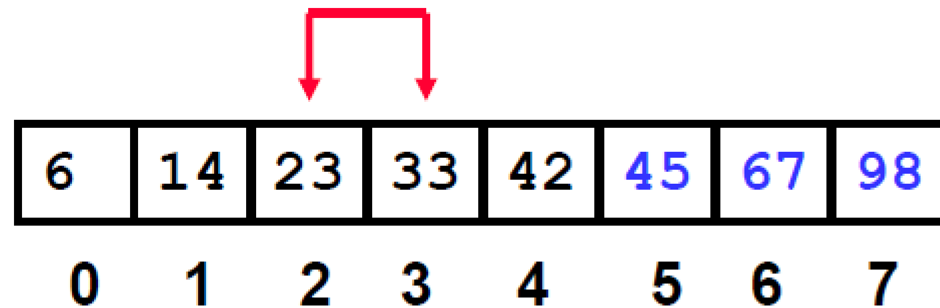


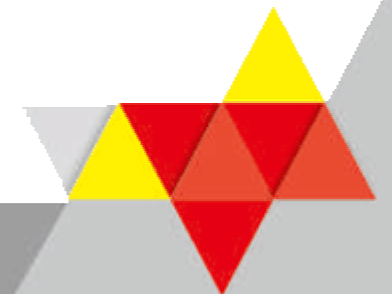


The Fourth "Bubble Up"

N	8
pos_akhir	3
index	2

did_swap: true





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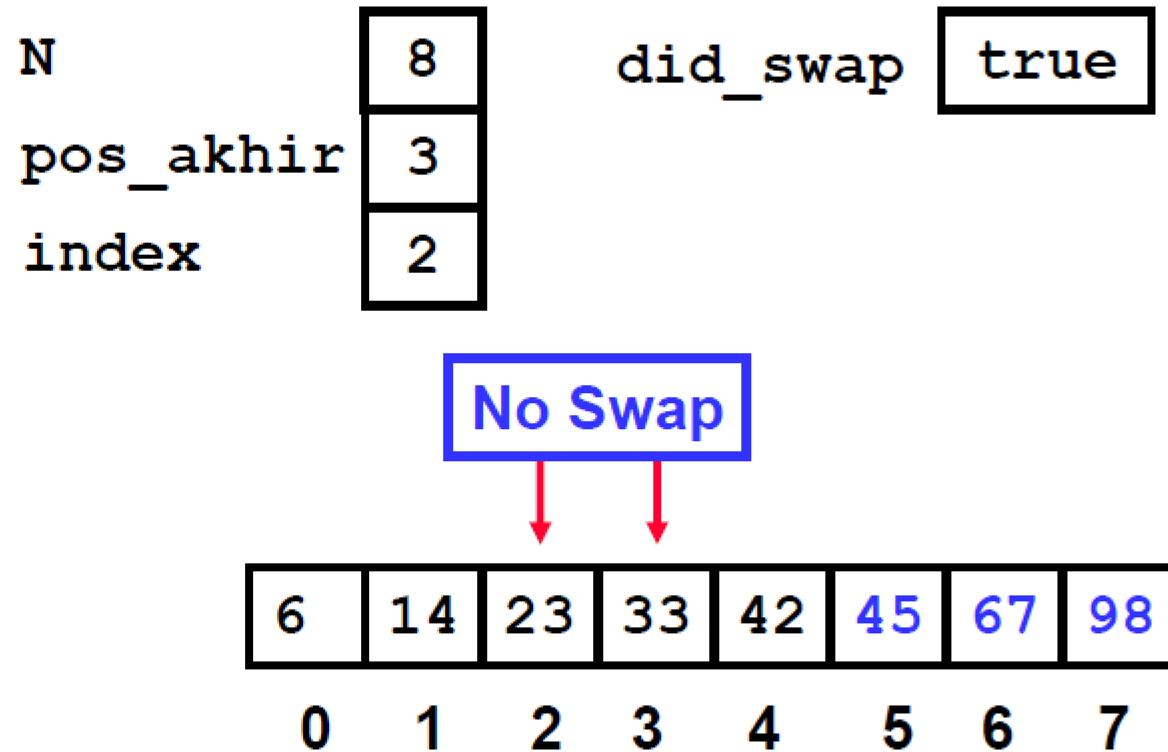
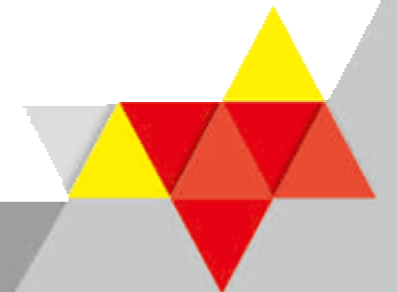
BUBBLE SORT

The Fourth "Bubble Up"

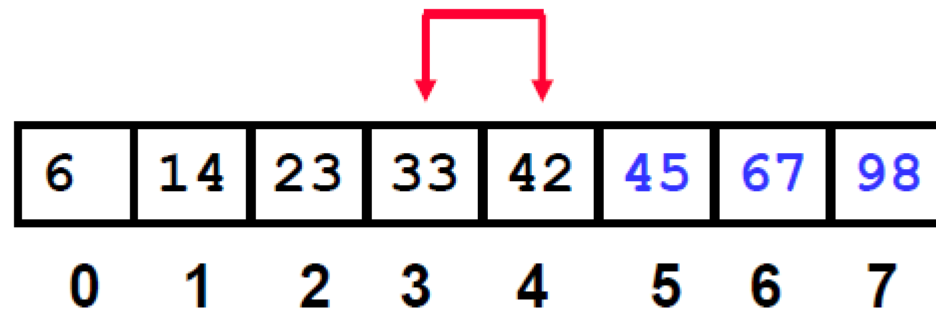


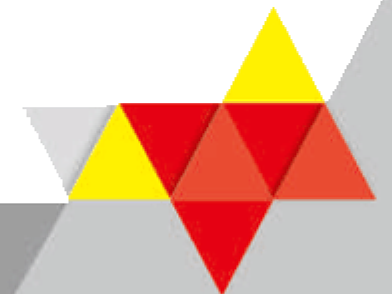


The Fourth "Bubble Up"

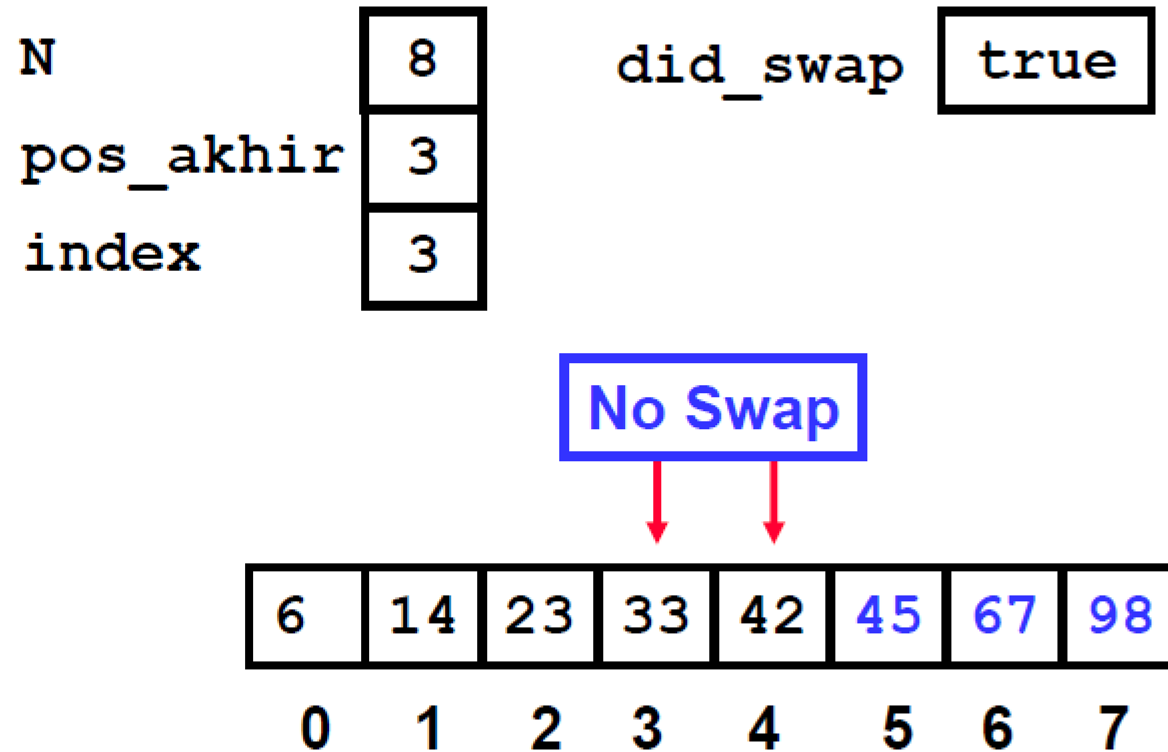
N	8
pos_akhir	3
index	3

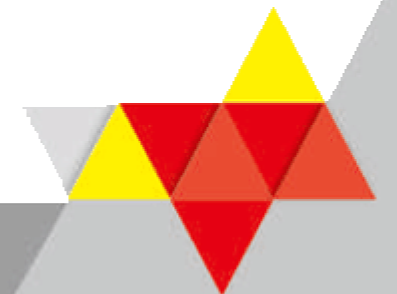
did_swap	true





The Fourth "Bubble Up"





After Fourth Pass of Outer Loop

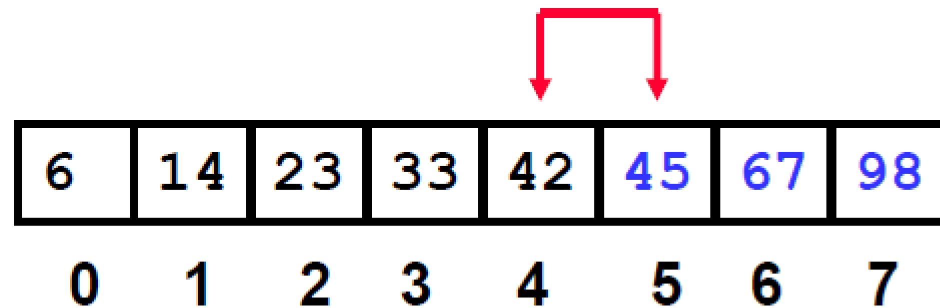
N 8

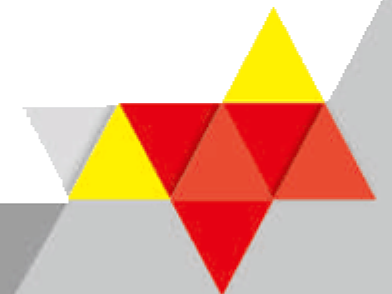
pos_akhir 3

index 4

did_swap true

Finished fourth "Bubble Up"

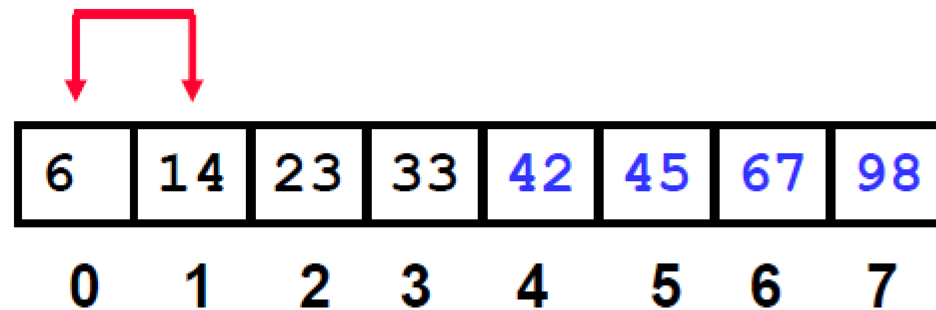


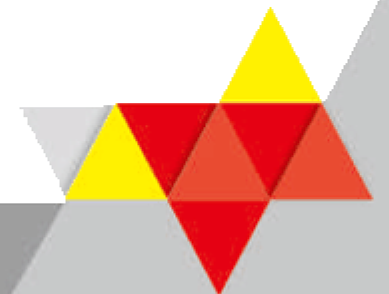


The Fifth “Bubble Up”

N	8
pos_akhir	2
index	0

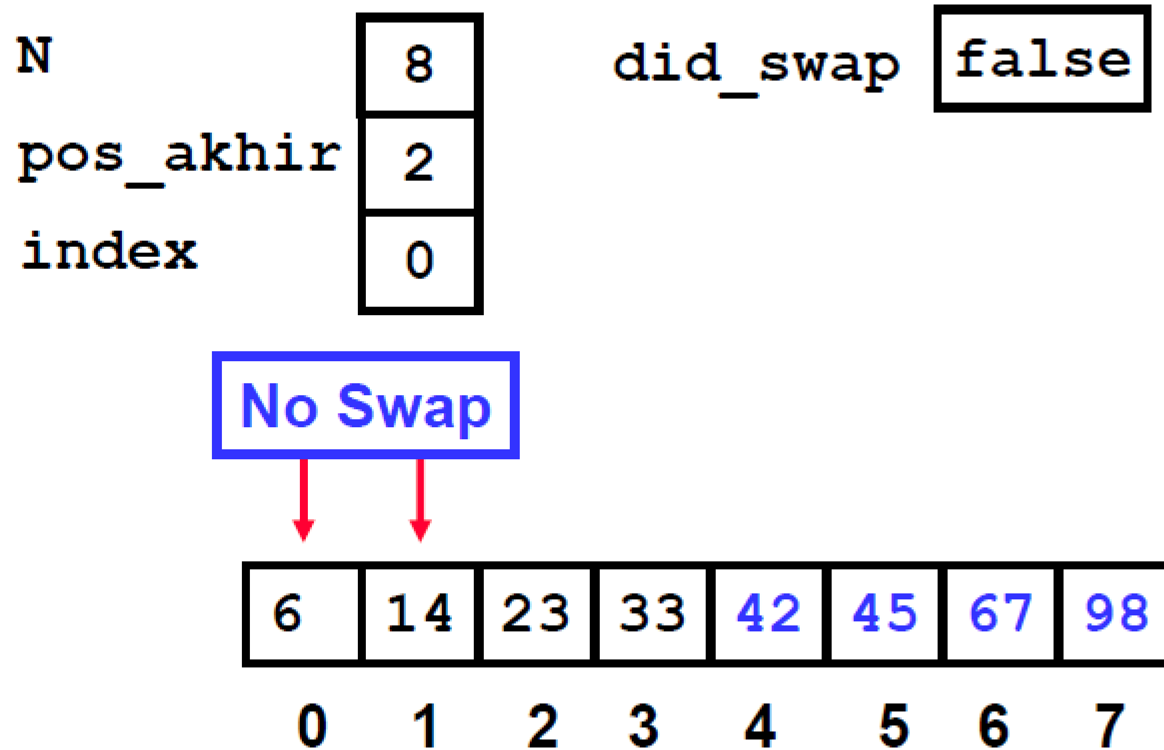
did_swap	false

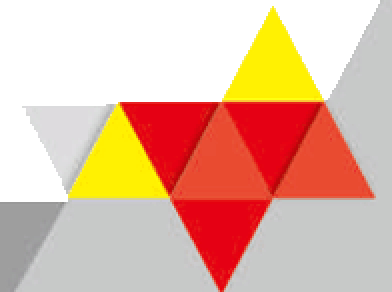




BUBBLE SORT

The Fifth “Bubble Up”

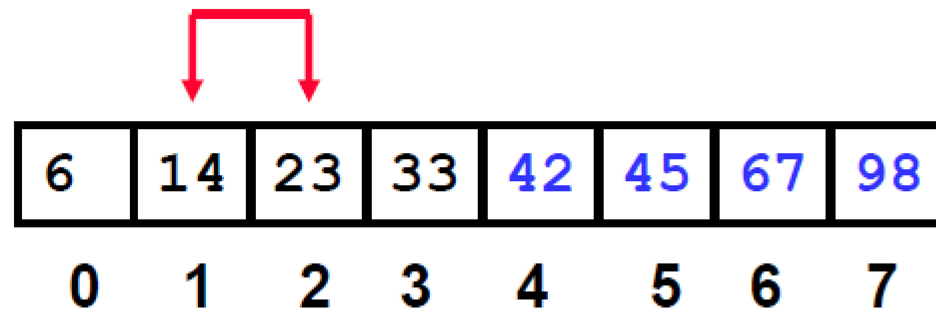


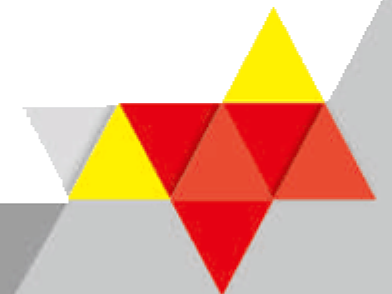


The Fifth “Bubble Up”

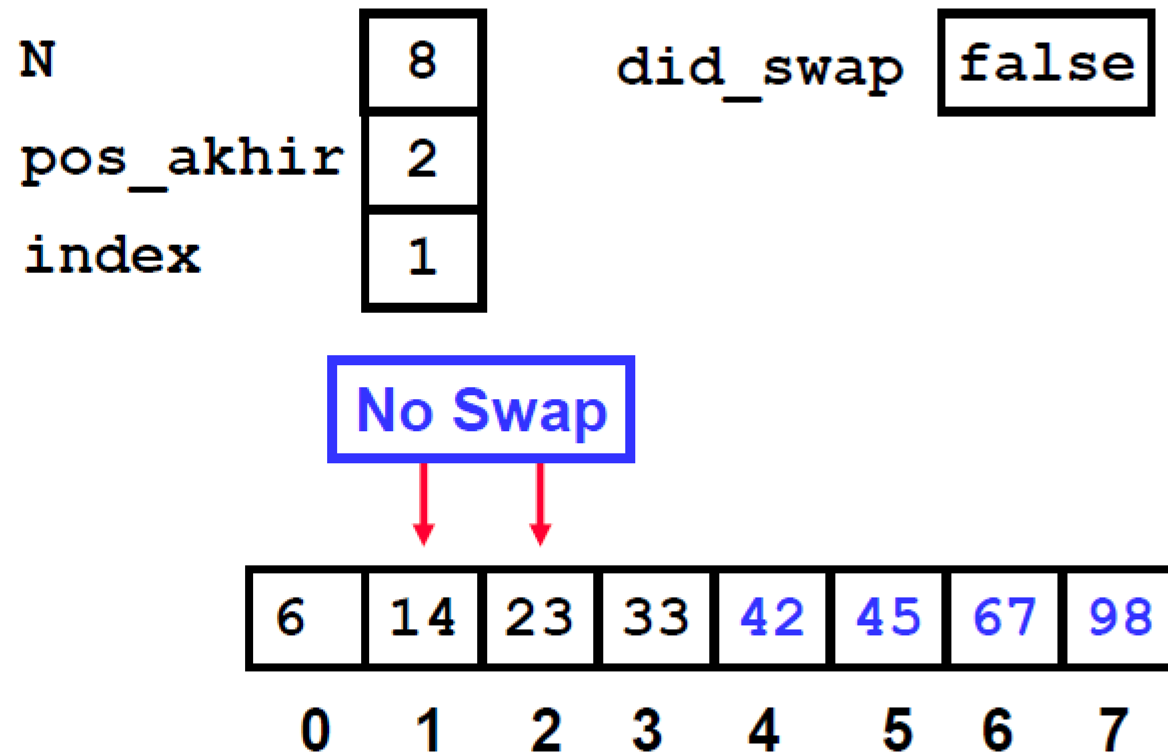
N	8
pos_akhir	2
index	1

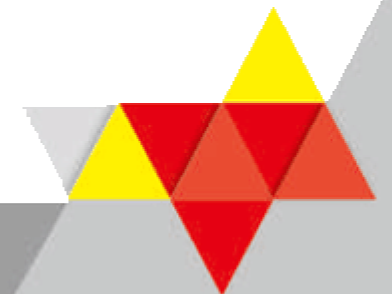
did_swap: false





The Fifth "Bubble Up"

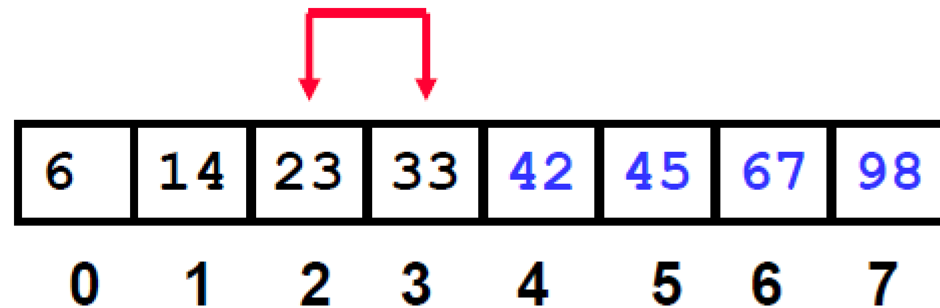


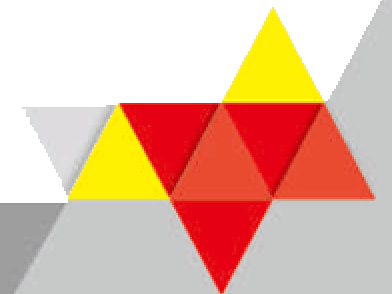


The Fifth “Bubble Up”

N	8
pos_akhir	2
index	2

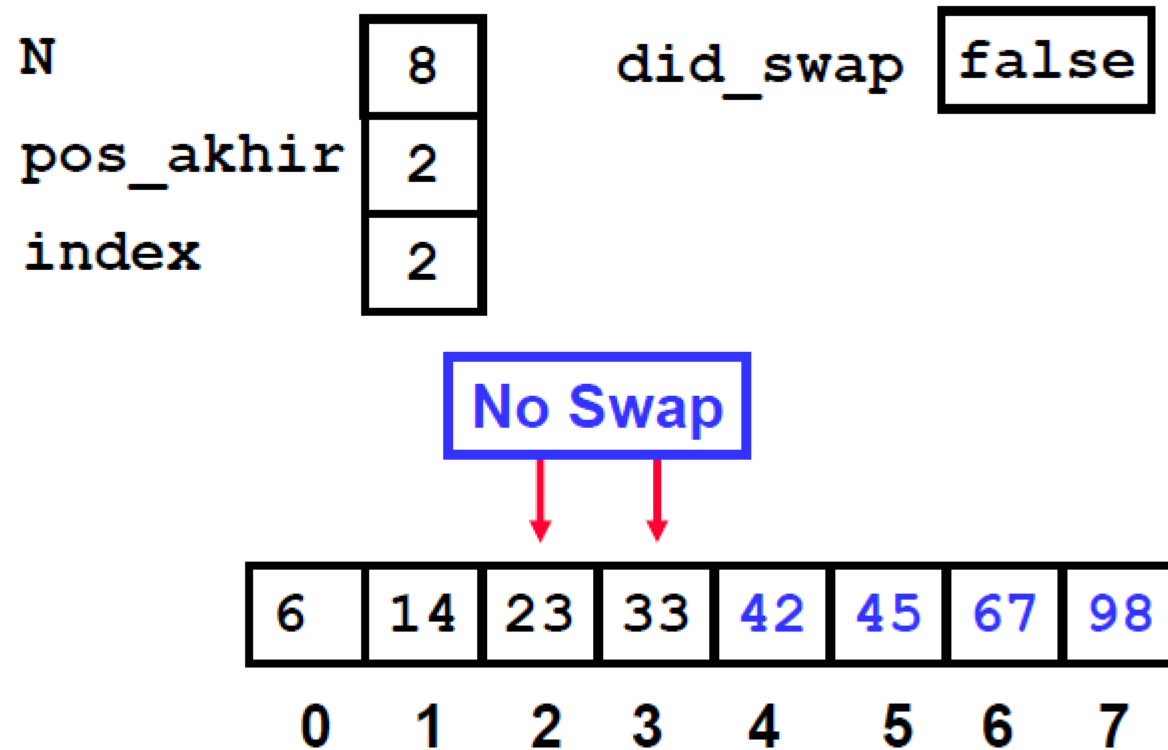
did_swap: false

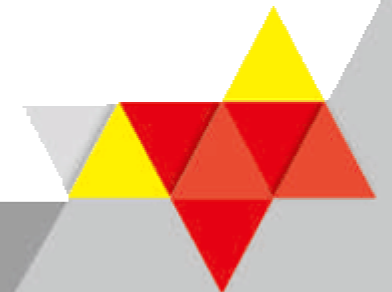




BUBBLE SORT

The Fifth "Bubble Up"



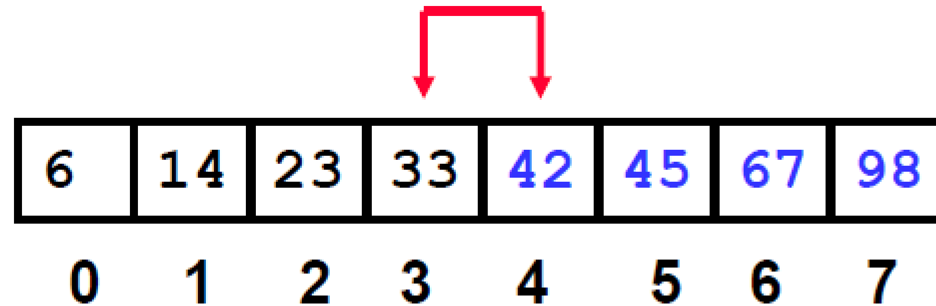


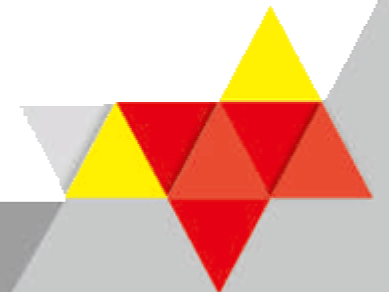
After Fifth Pass of Outer Loop

N	8
pos_akhir	2
index	3

did_swap: false

Finished fifth "Bubble Up"





Finished "Early"

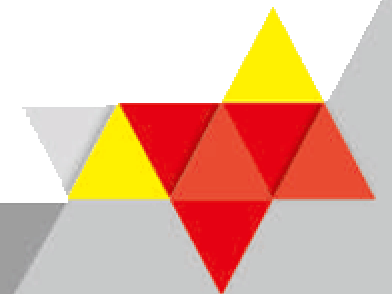
N	8
pos_akhir	2
index	3

did_swap: false

We didn't do any swapping, so all of the other elements must be correctly placed.

We can "skip" the last two passes of the outer loop.

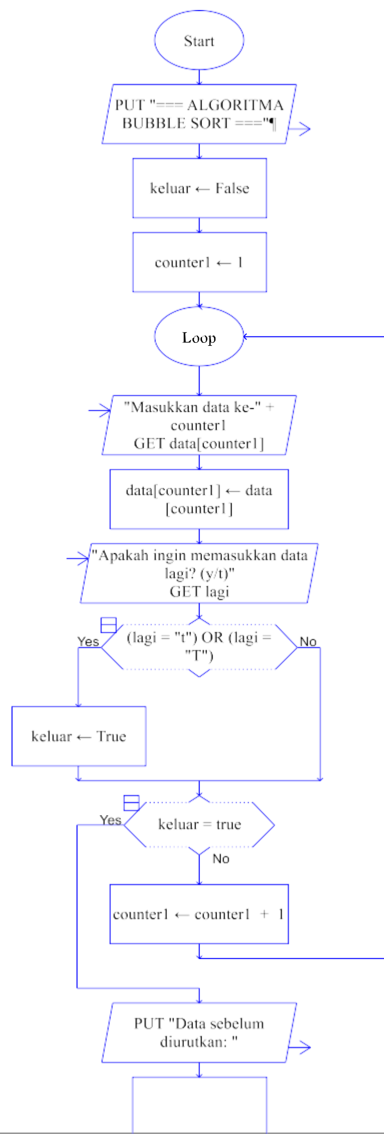
6	14	23	33	42	45	67	98
0	1	2	3	4	5	6	7

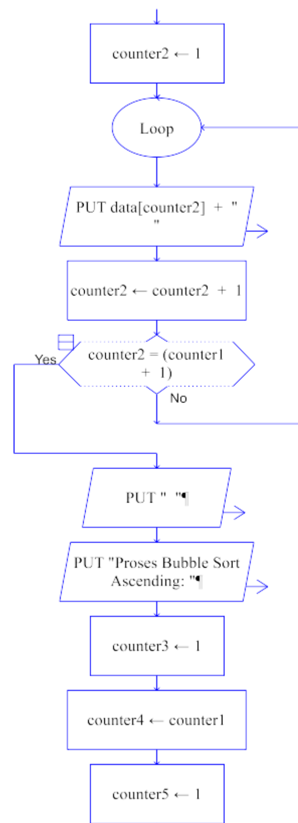


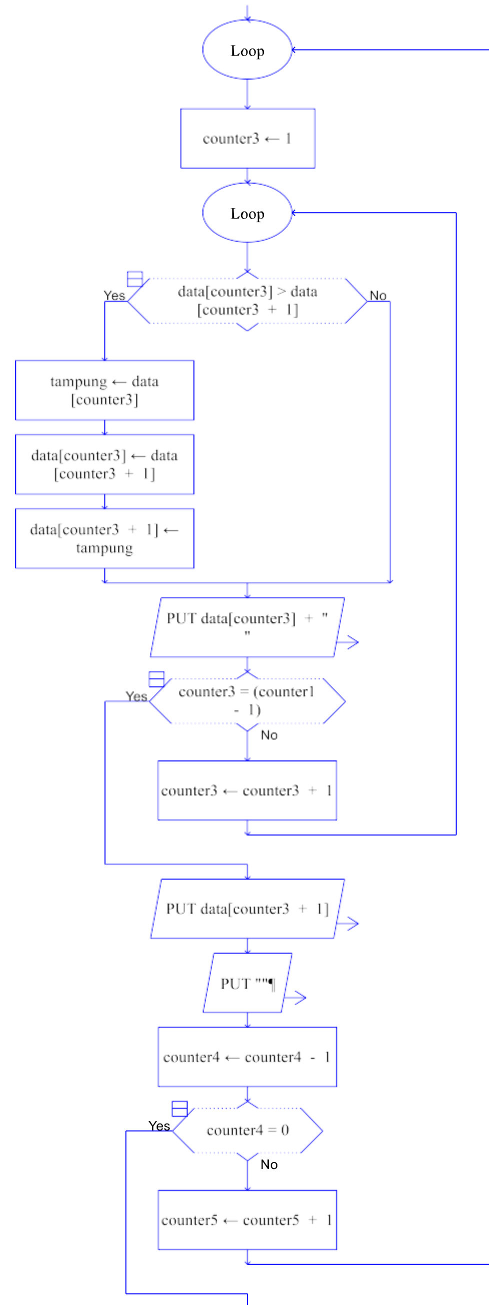
Algoritma

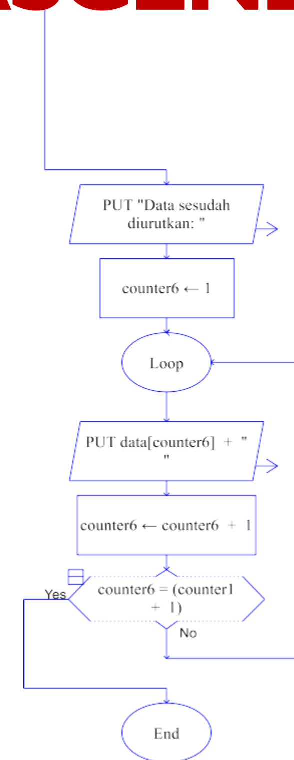
1. i ← N
2. selama (i >0) kerjakan baris 3 sampai dengan 11
3. did_swap = false
4. j ← 1
5. Selama (j < i) kerjakan baris 5 sampai dengan 8
6. Jika (Data[j-1] > Data[j]) maka kerjakan baris 7 & 8
7. tukar Data[j-1] dengan Data[j]
8. did_swap = true
9. j ← j + 1
10. Jika did_swap = false keluar dari loop
11. i ← i - 1

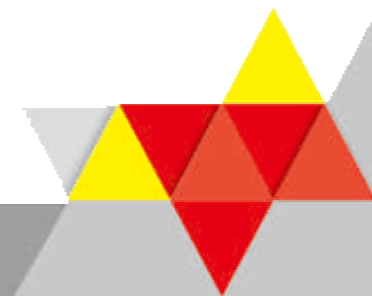
BUBBLE SORT ASCENDING



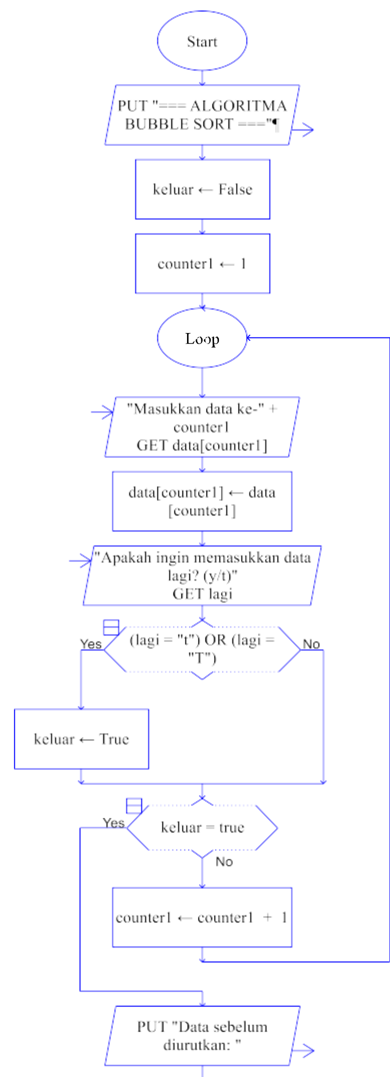


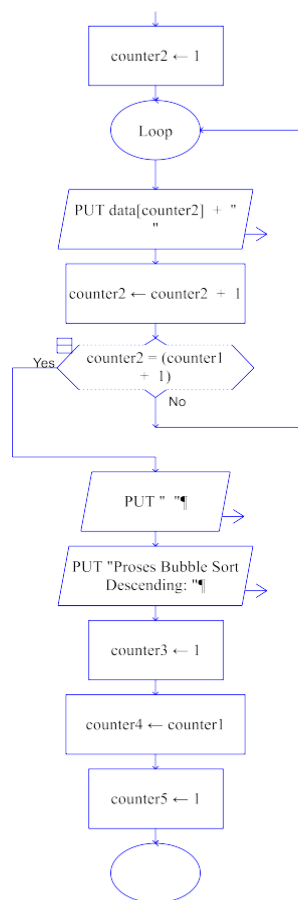


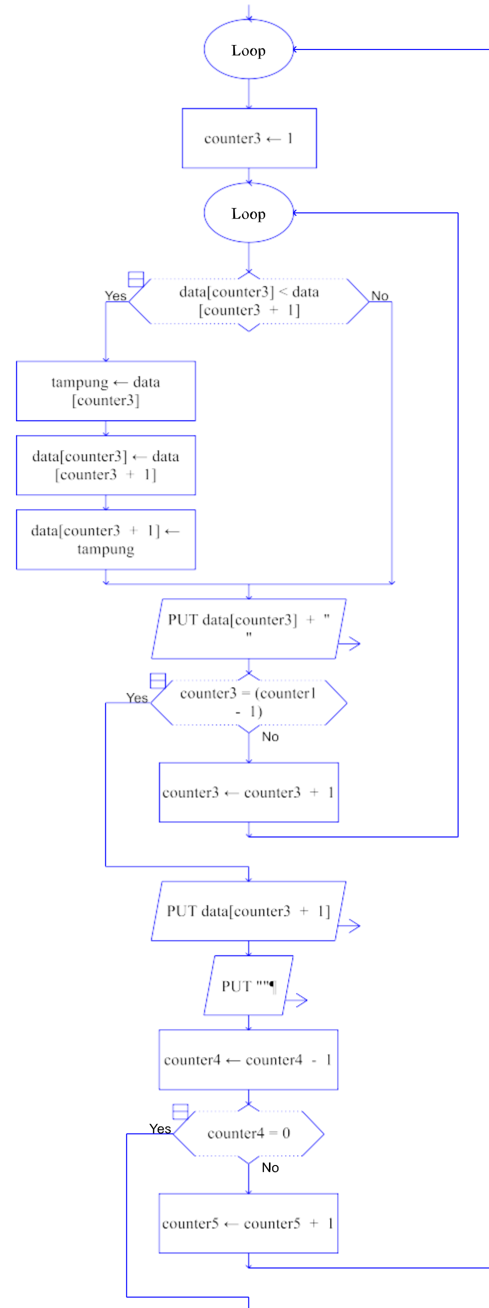


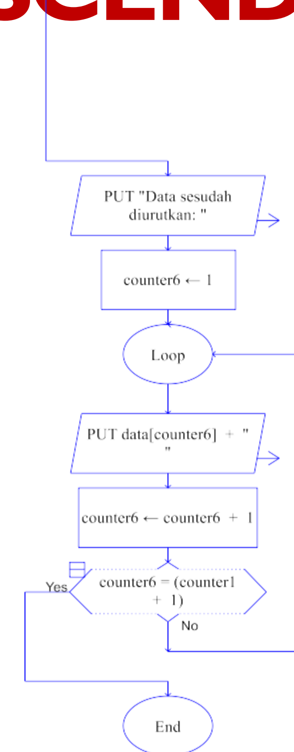


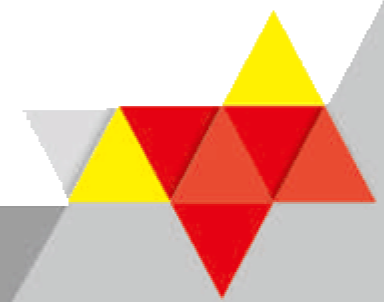
BUBBLE SORT DESCENDING



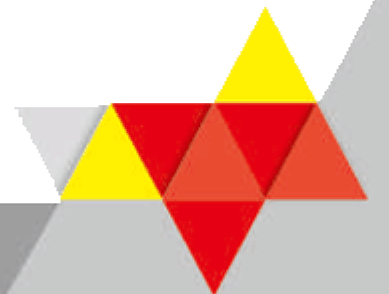




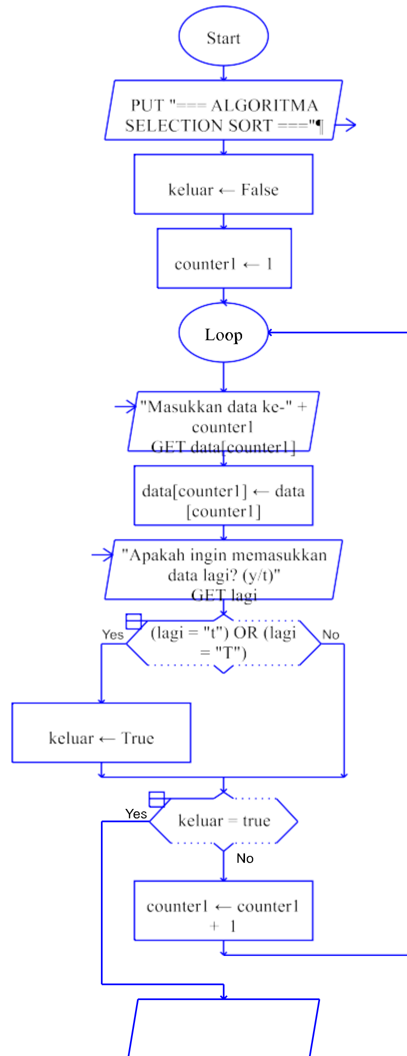


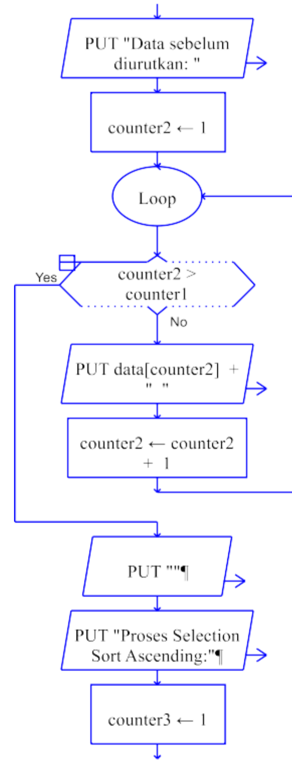


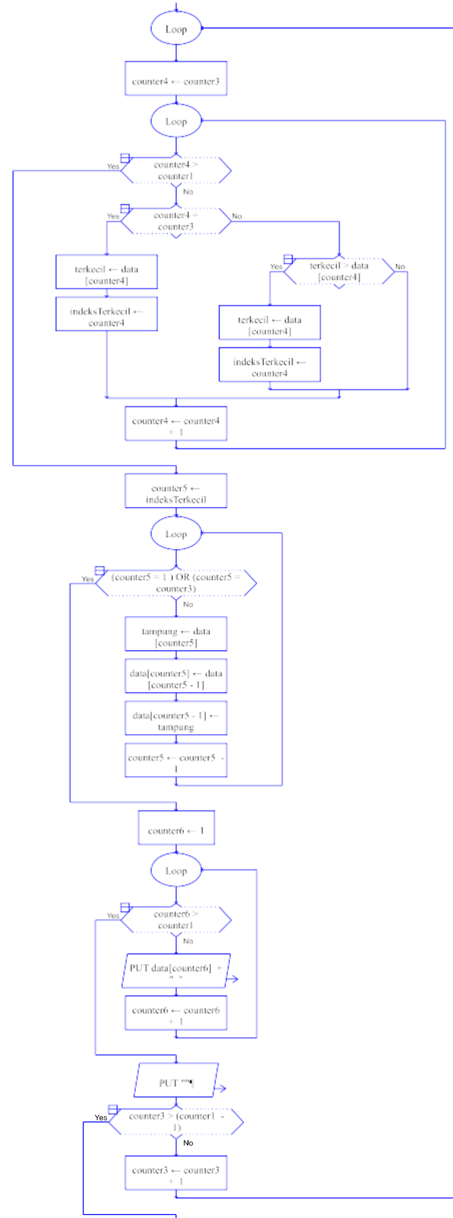
2. SELECTION SORT

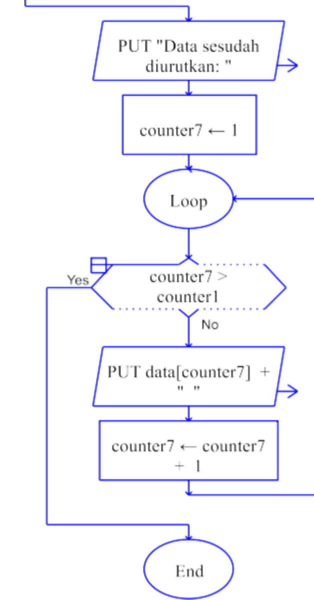


SELECTION SORT ASCENDING









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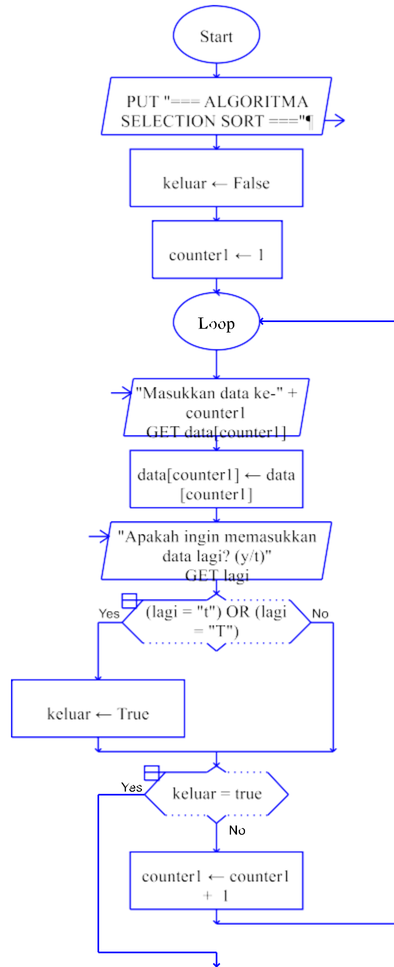
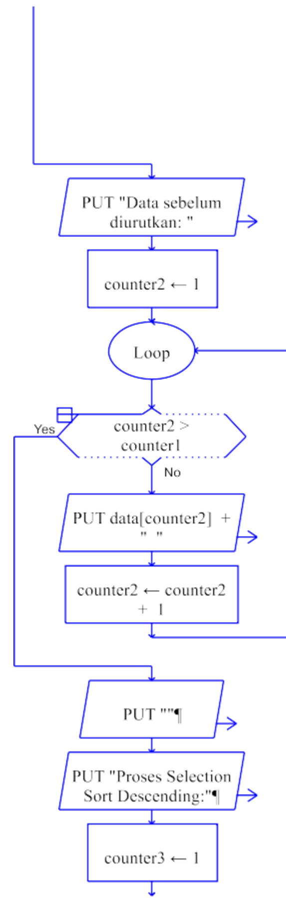
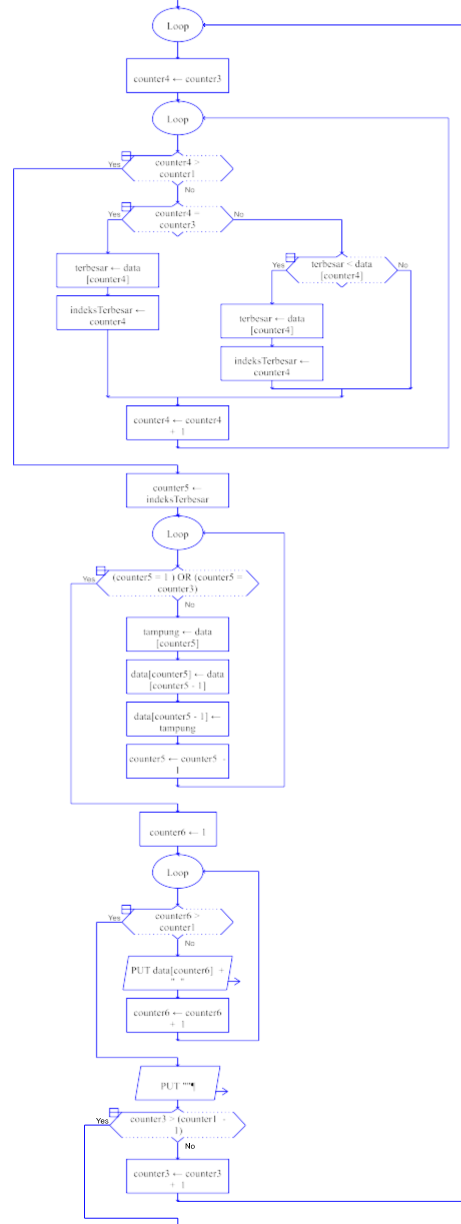
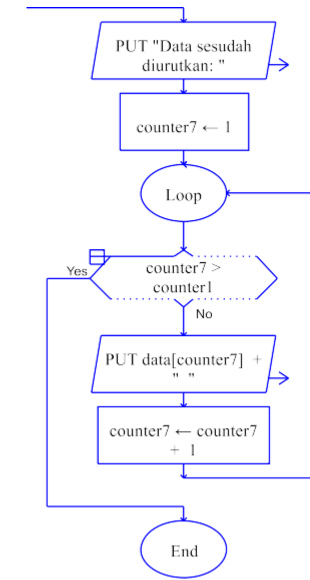
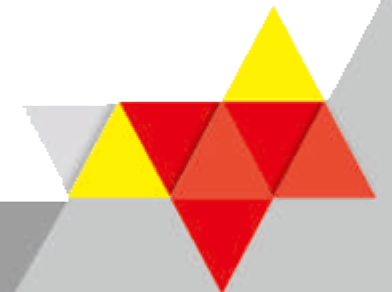
SELECTION SORT DESCENDING



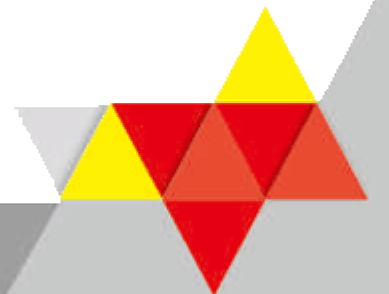








3. MERGE SORT



Divide and Conquer

- **Metode Divide and Conquer, setiap kali memecah persoalan menjadi setengahnya, namun menggunakan hasil dari kedua bagian tersebut:**
  - **memotong permasalahan menjadi dua bagian hingga permasalahan trivial → tidak ber-problem lagi**
  - **menyelesaikan untuk dua bagian**
  - **mengkombinasikan penyelesaian**

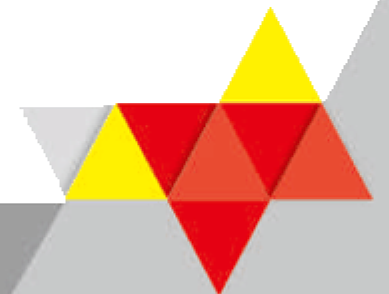
MERGE SORT

- *A divide-and-conquer algorithm:*
  Membagi unsorted array menjadi 2 bagian hingga menghasilkan sub-arrays yang hanya berisi satu elemen
- *Merge together* solusi dari sub-problem

  HOW?

  - Bandingkan elemen pertama dari 2 sub-array
  - Ambil elemen yang terkecil dan letakkan pada array hasil
  - Teruskan proses pembandingan dan pengambilan, sampai seluruh elemen sub-array dipindahkan ke array hasil

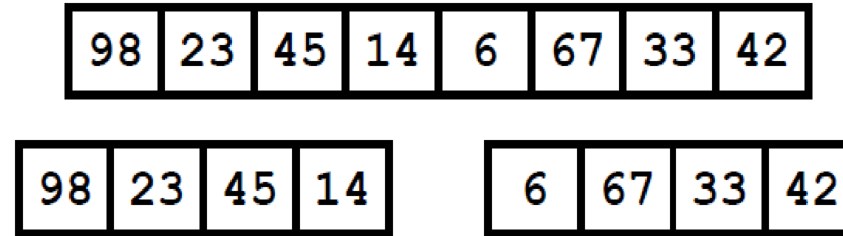
37	23	6	89	15	12	2	19

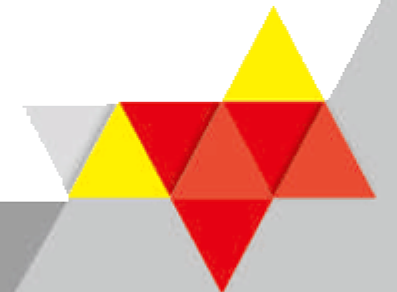


MERGE SORT

98	23	45	14	6	67	33	42

MERGE SORT





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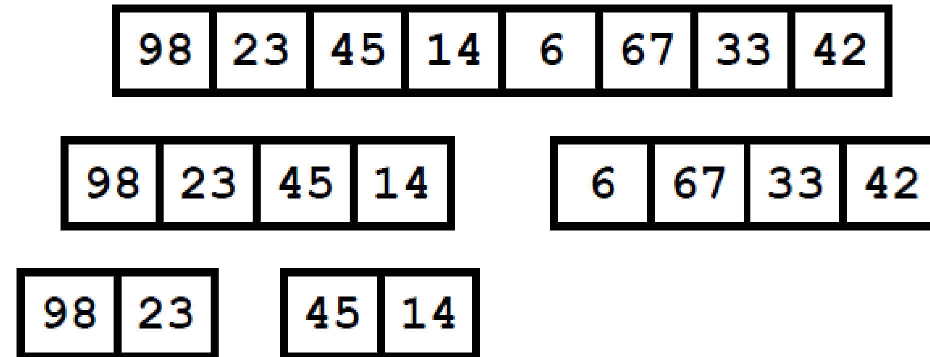

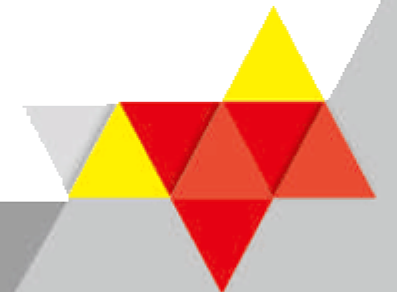

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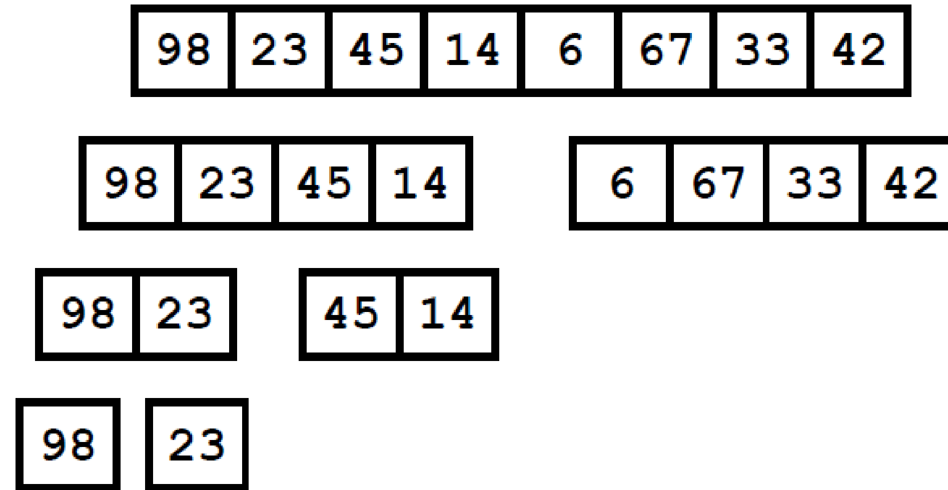

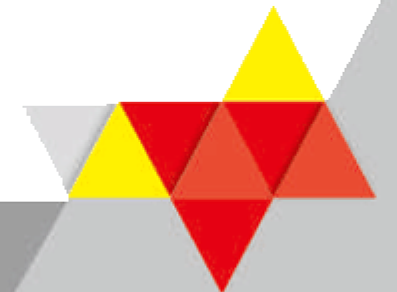

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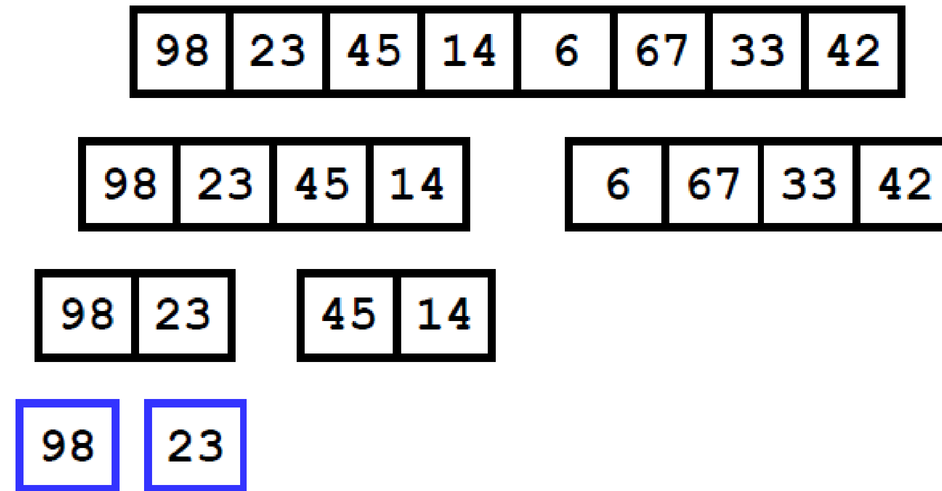

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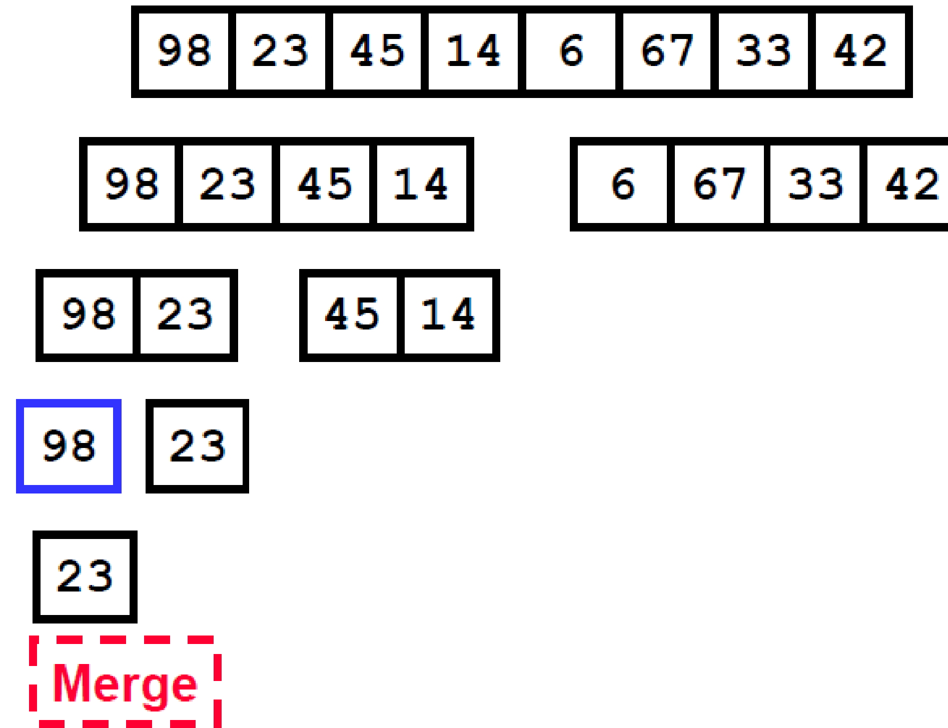

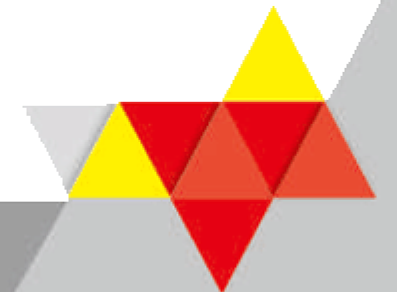

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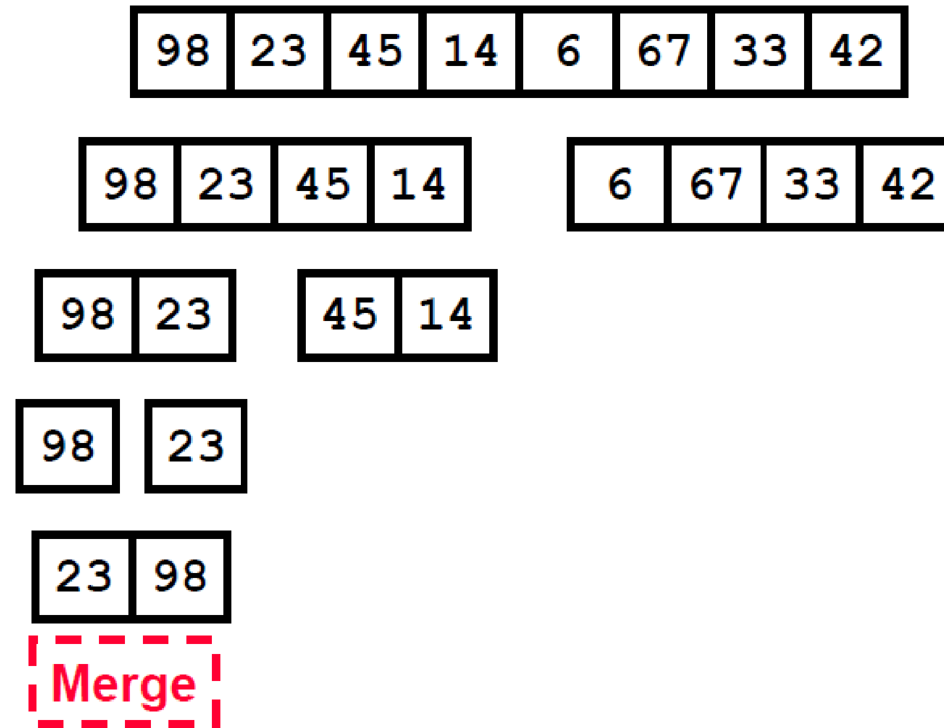

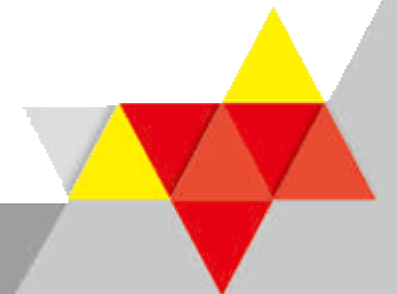

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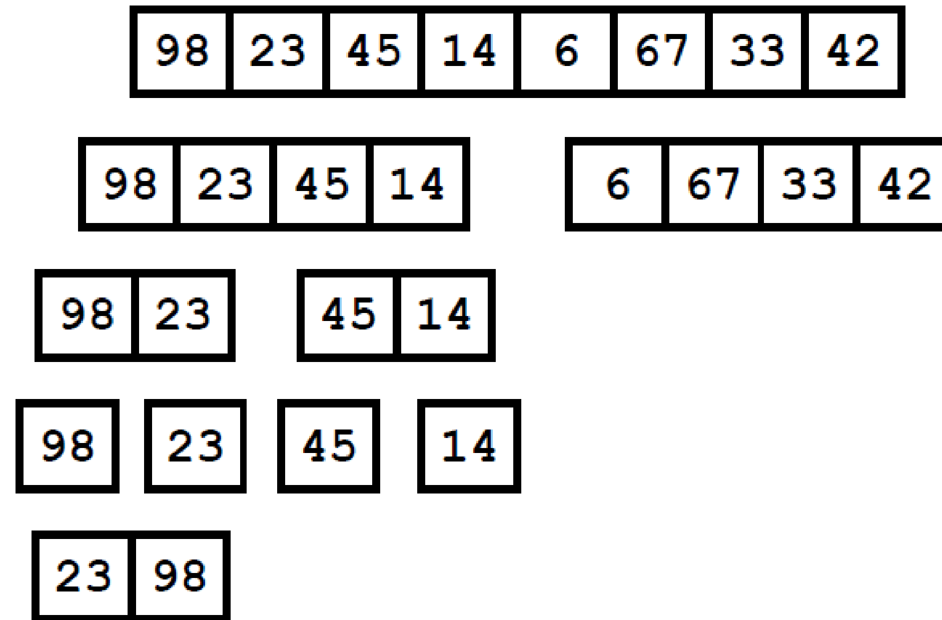

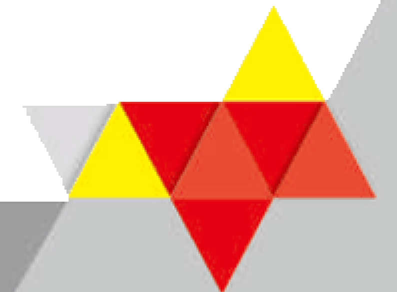

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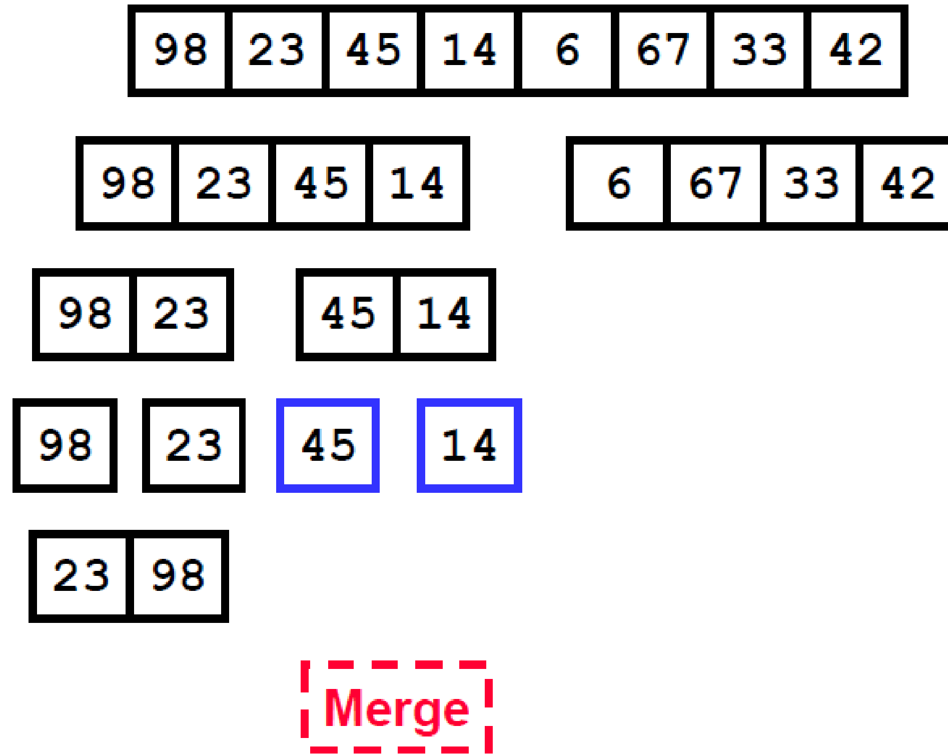

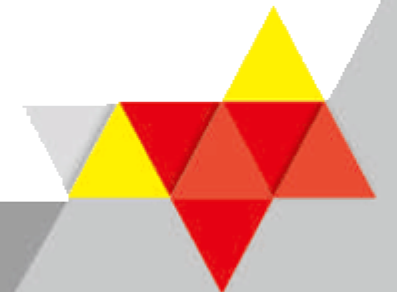

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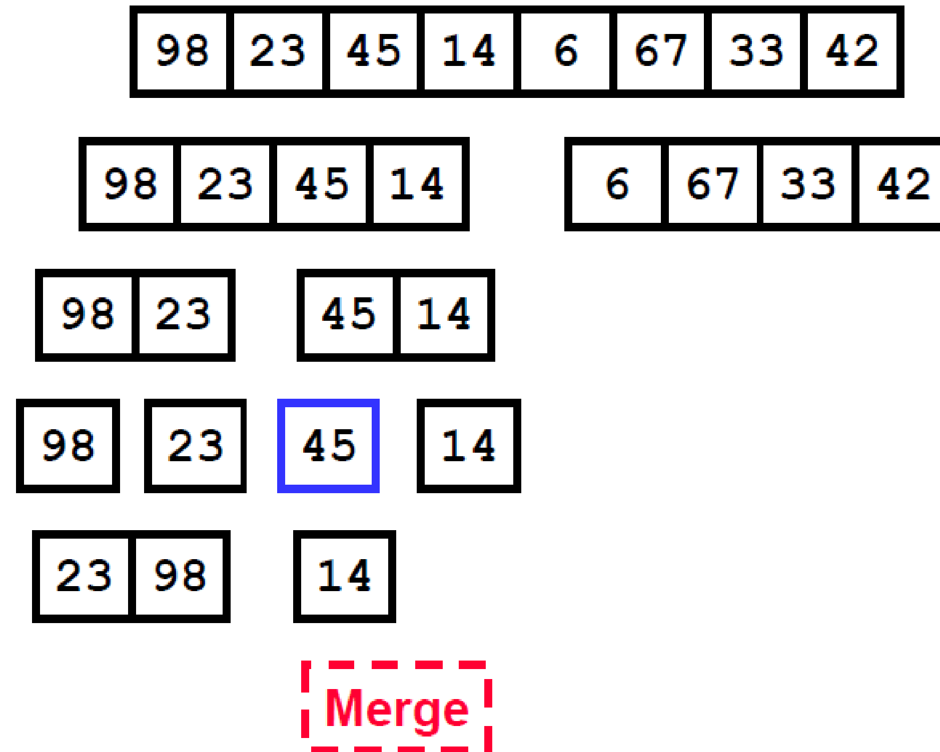

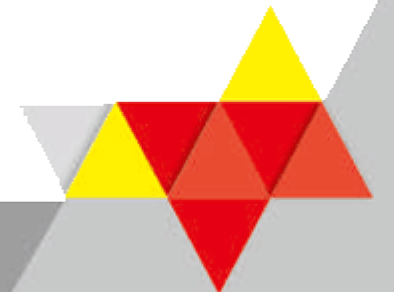

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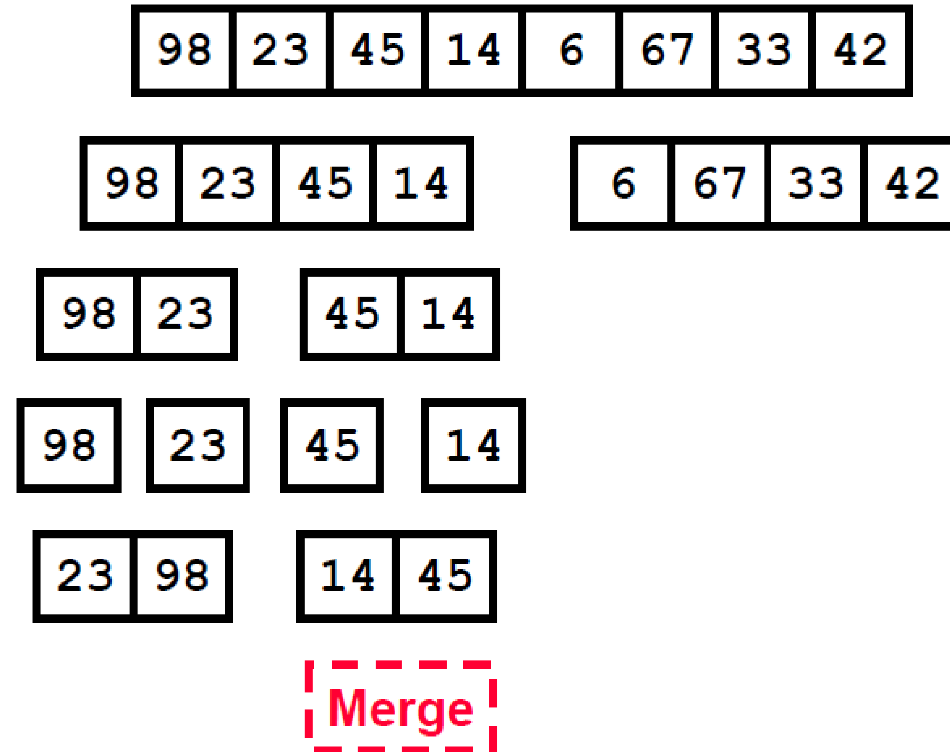

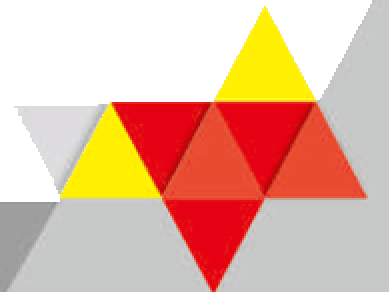

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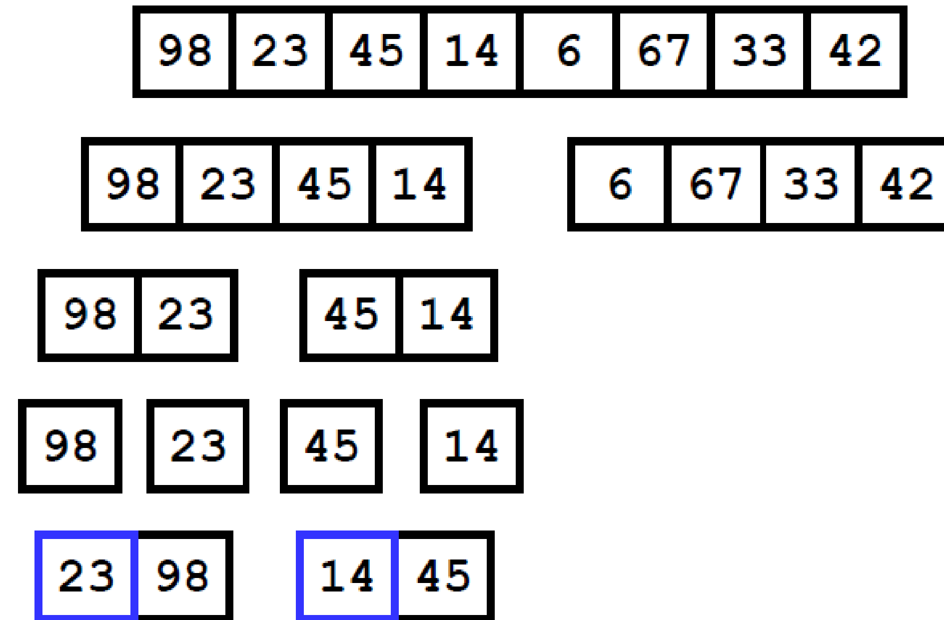

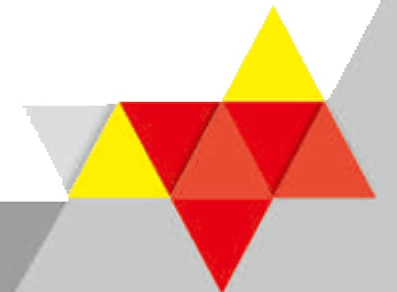

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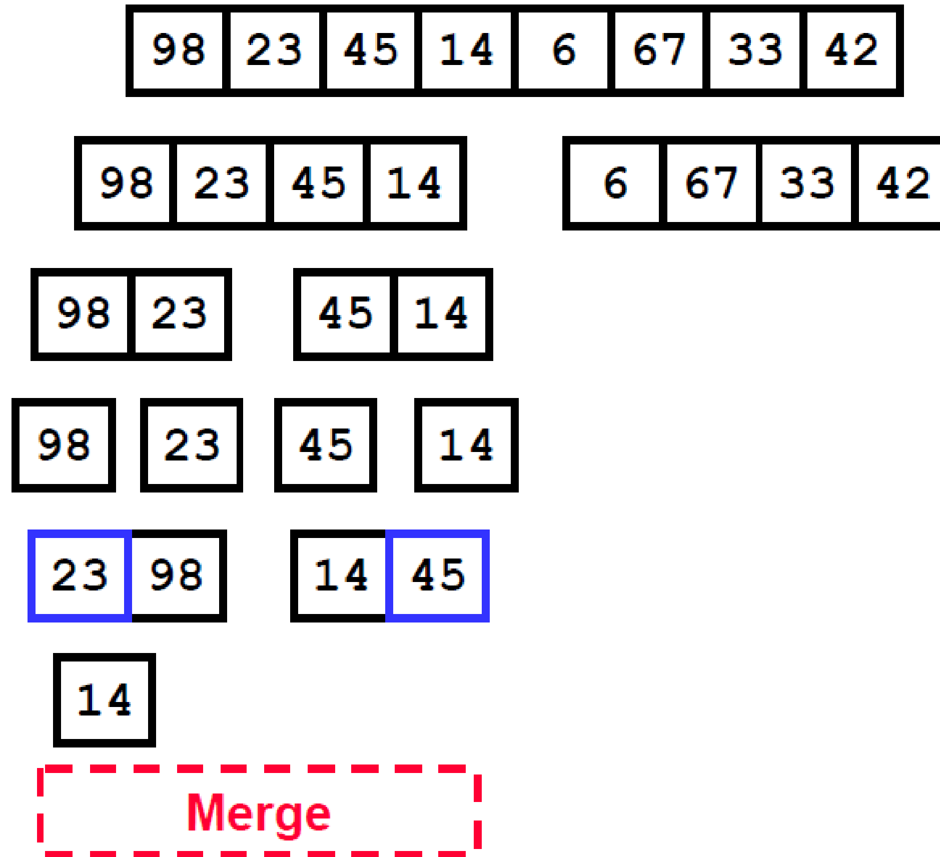

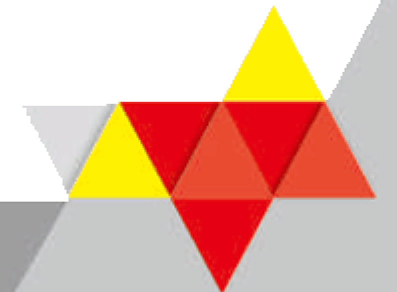

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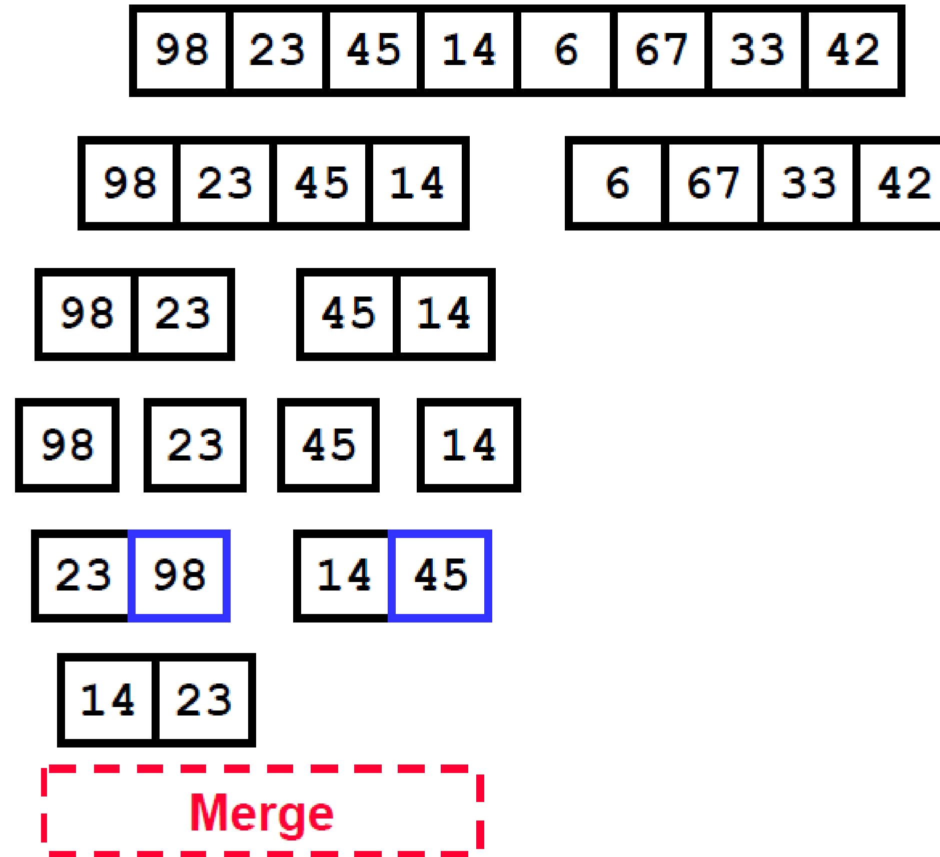

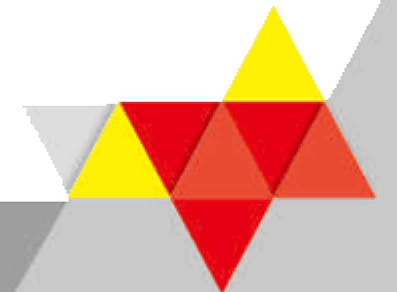

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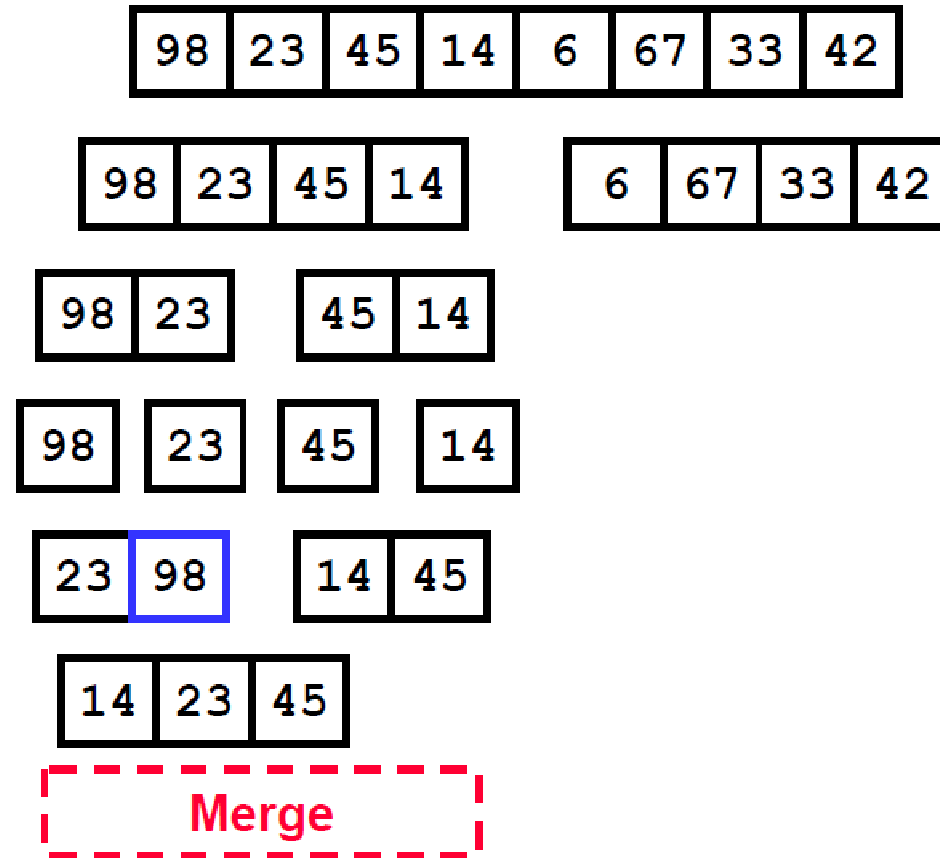

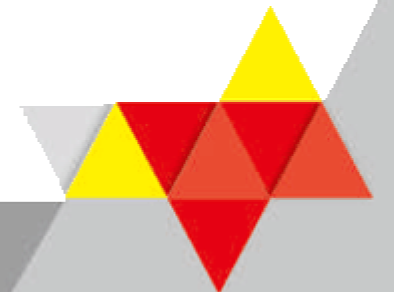

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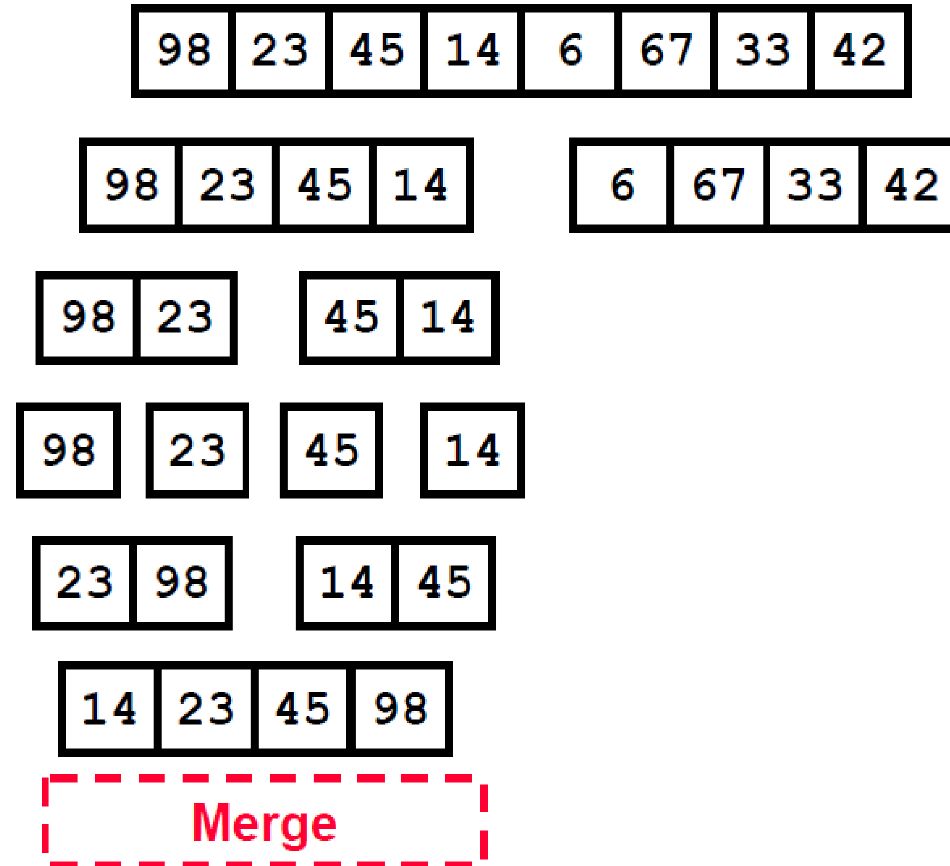

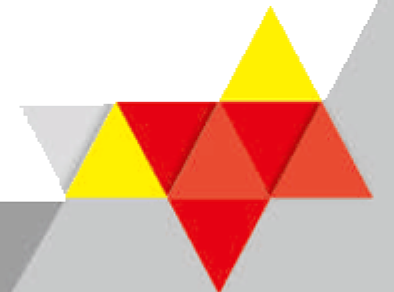

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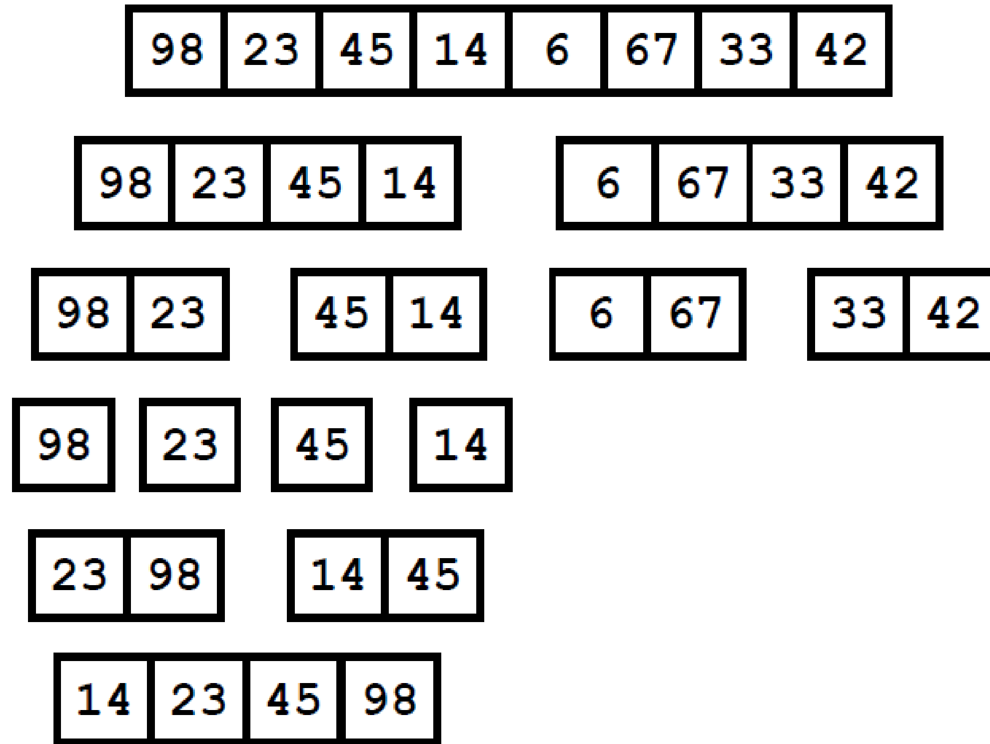

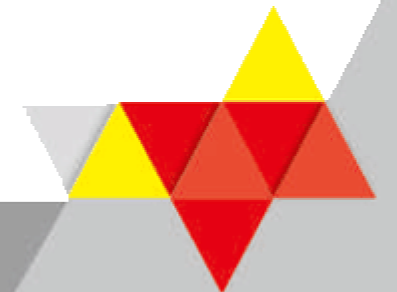

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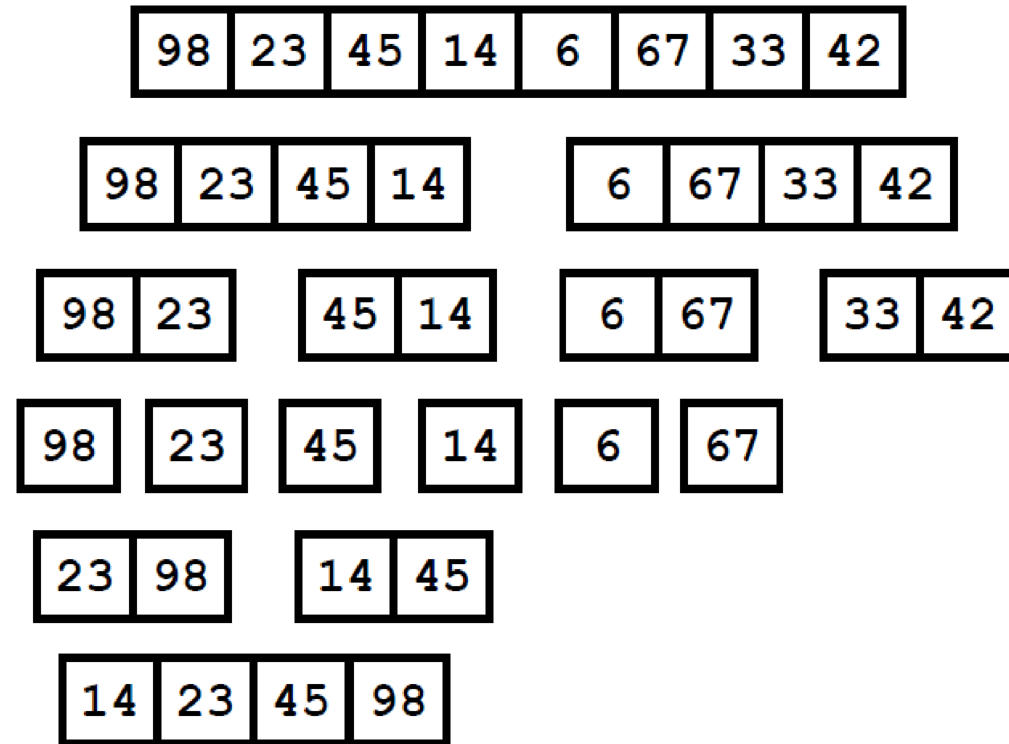

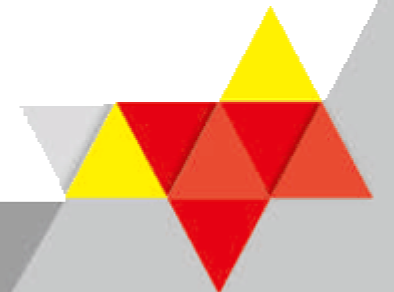

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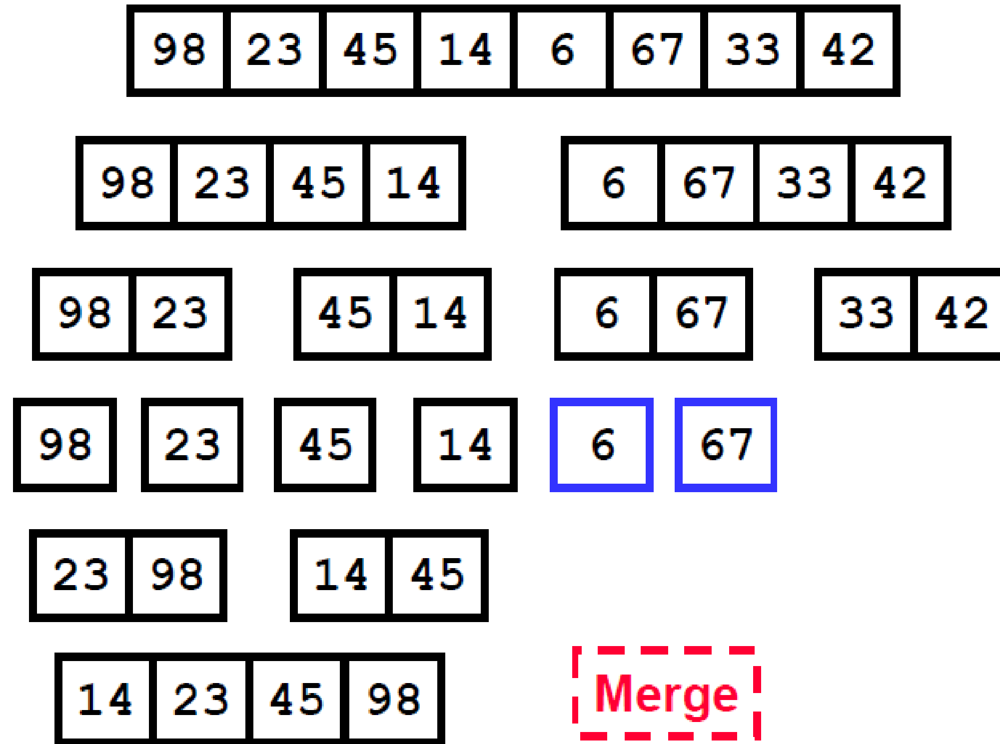

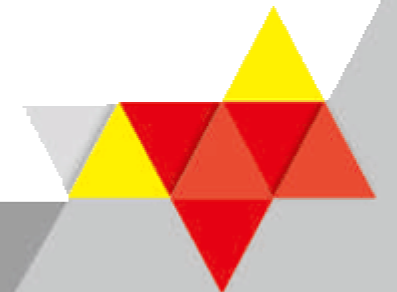

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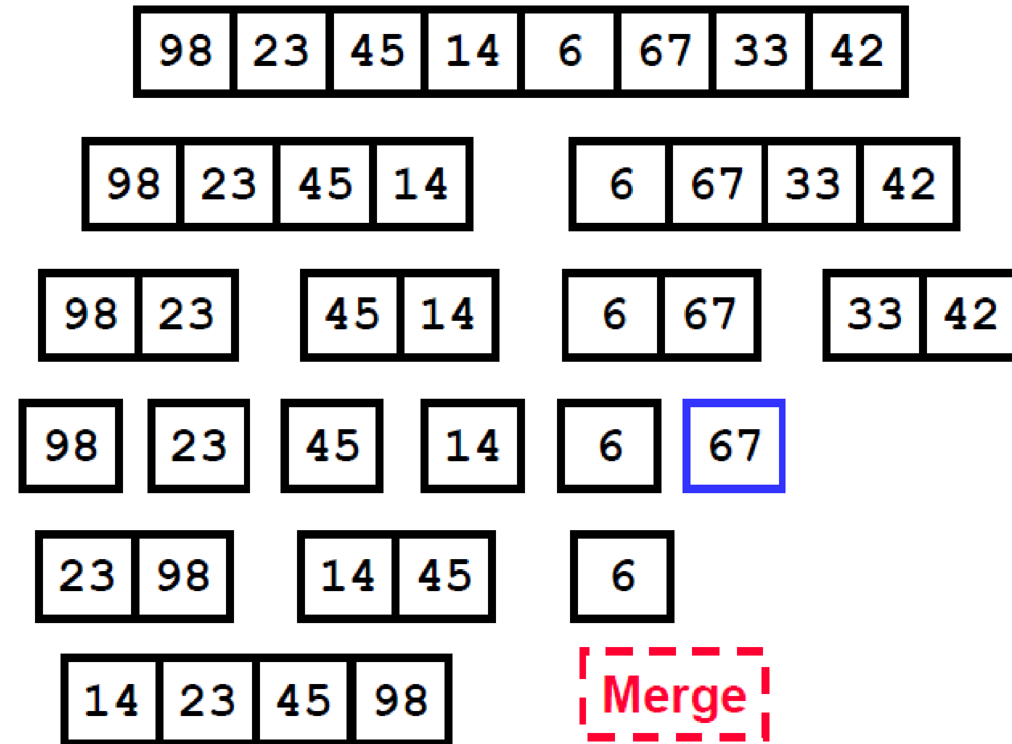
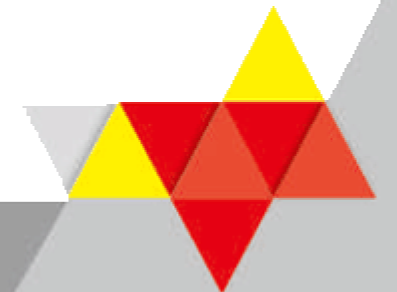
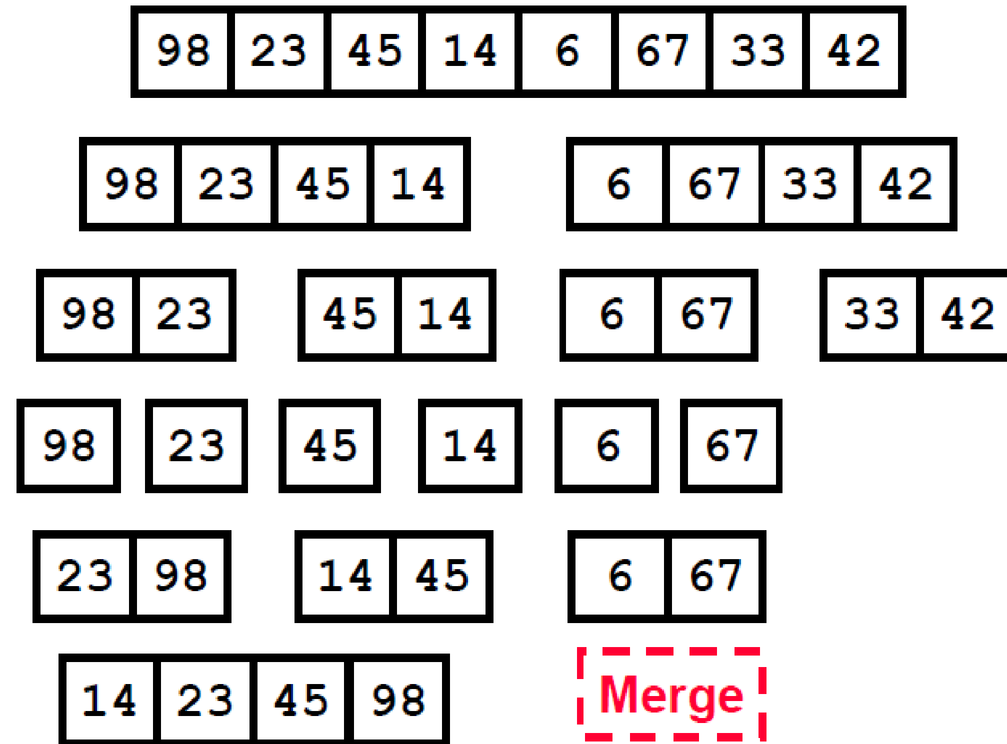
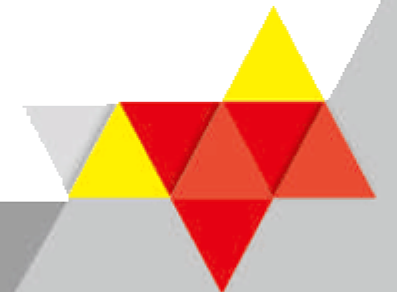




MERGE SORT





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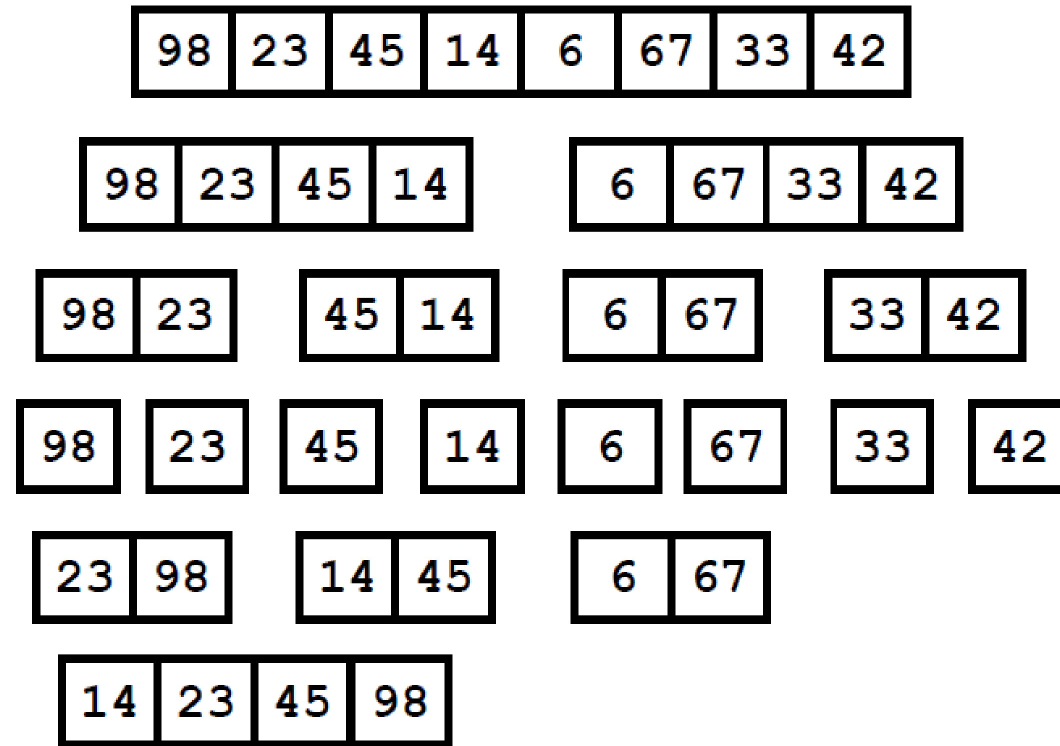

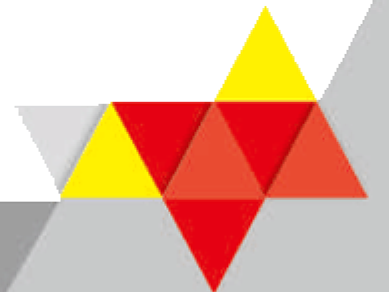

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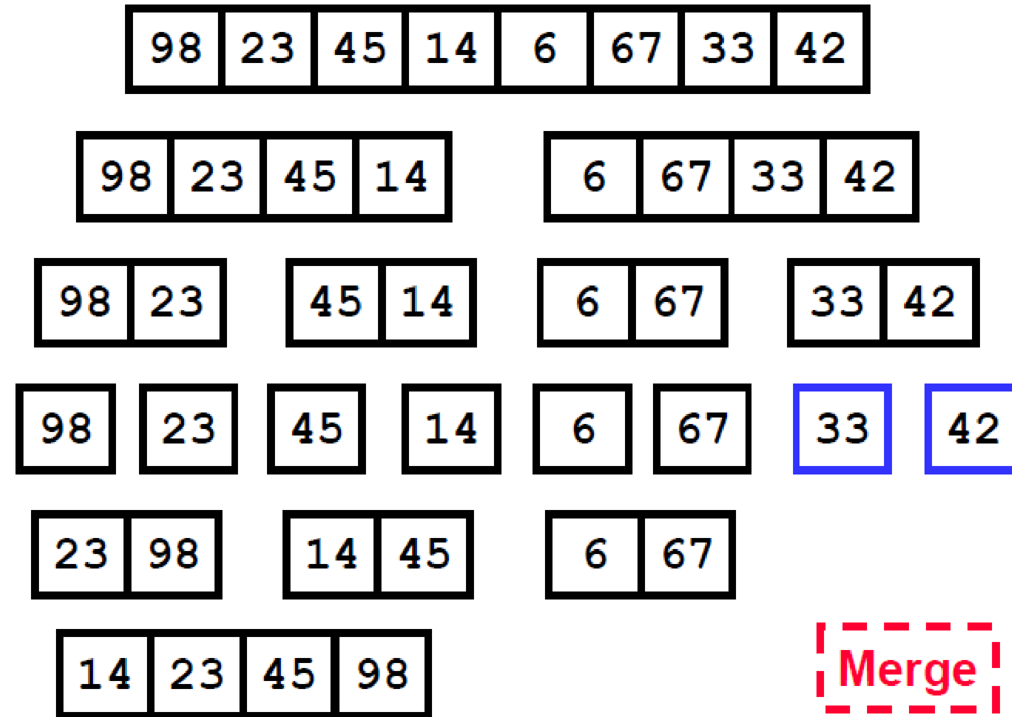

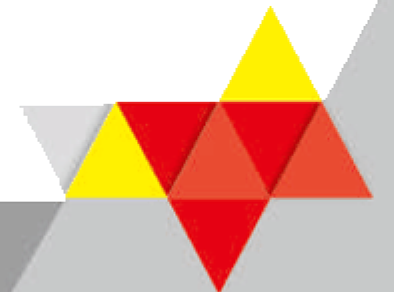

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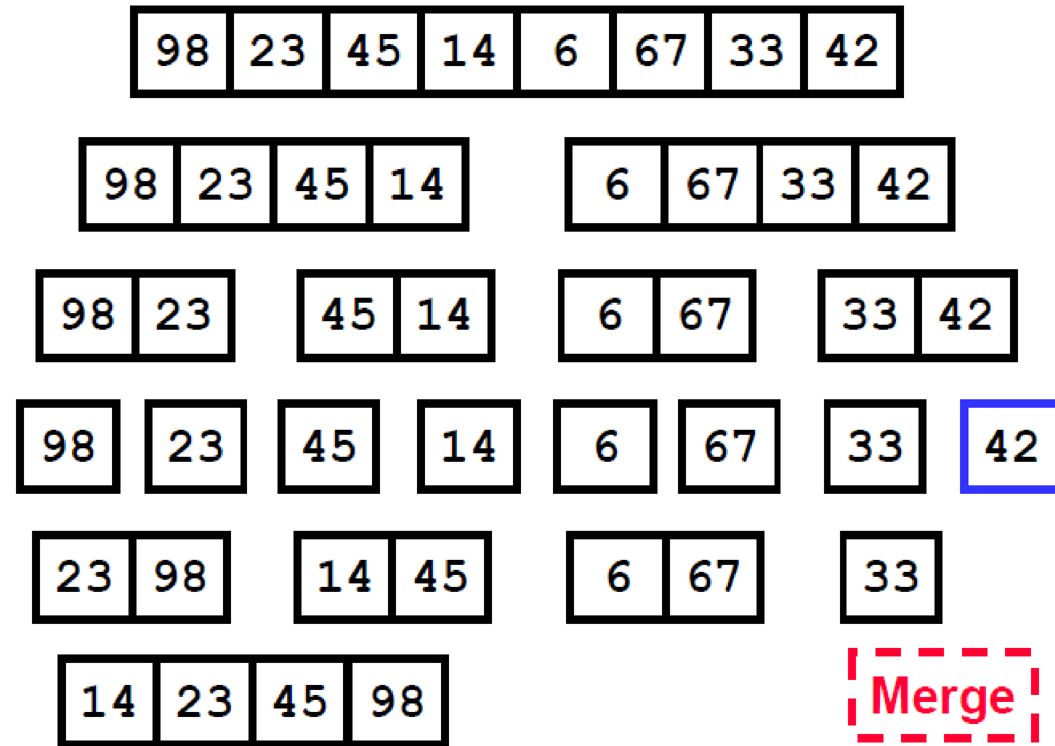

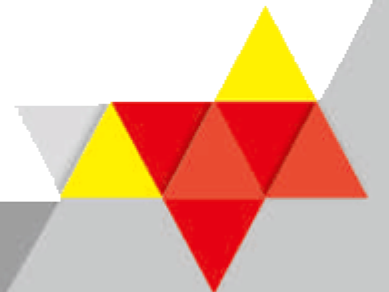

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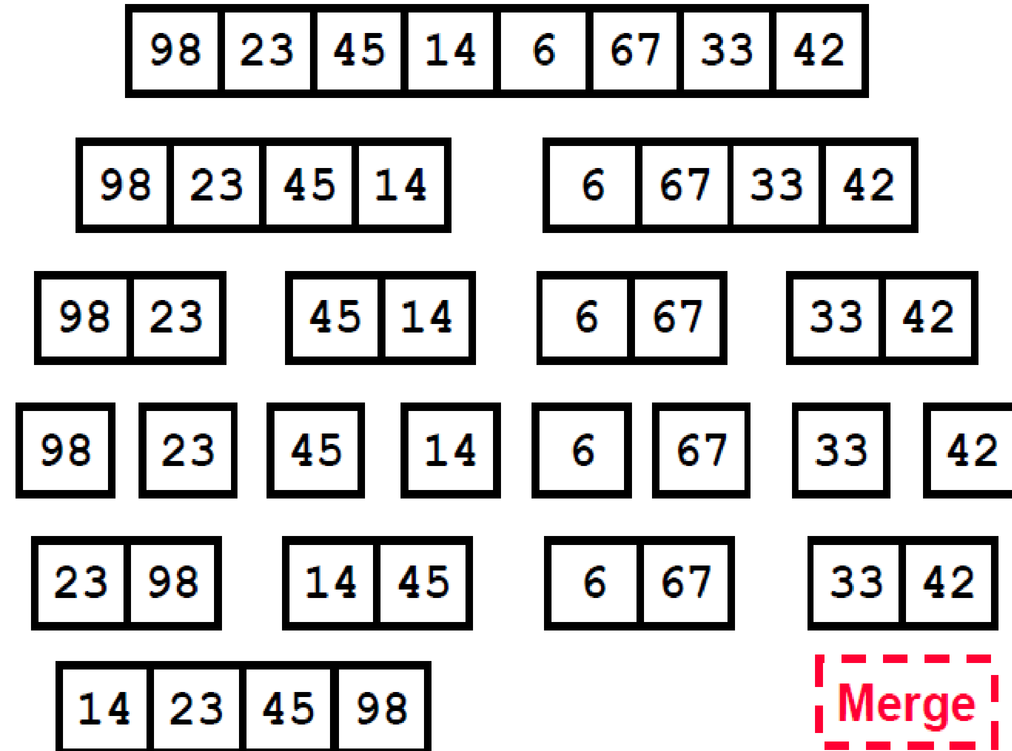

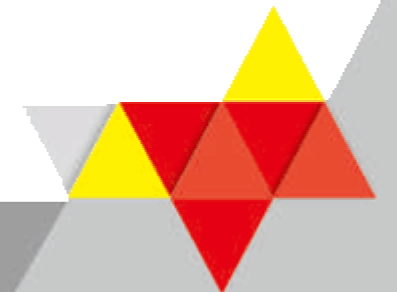

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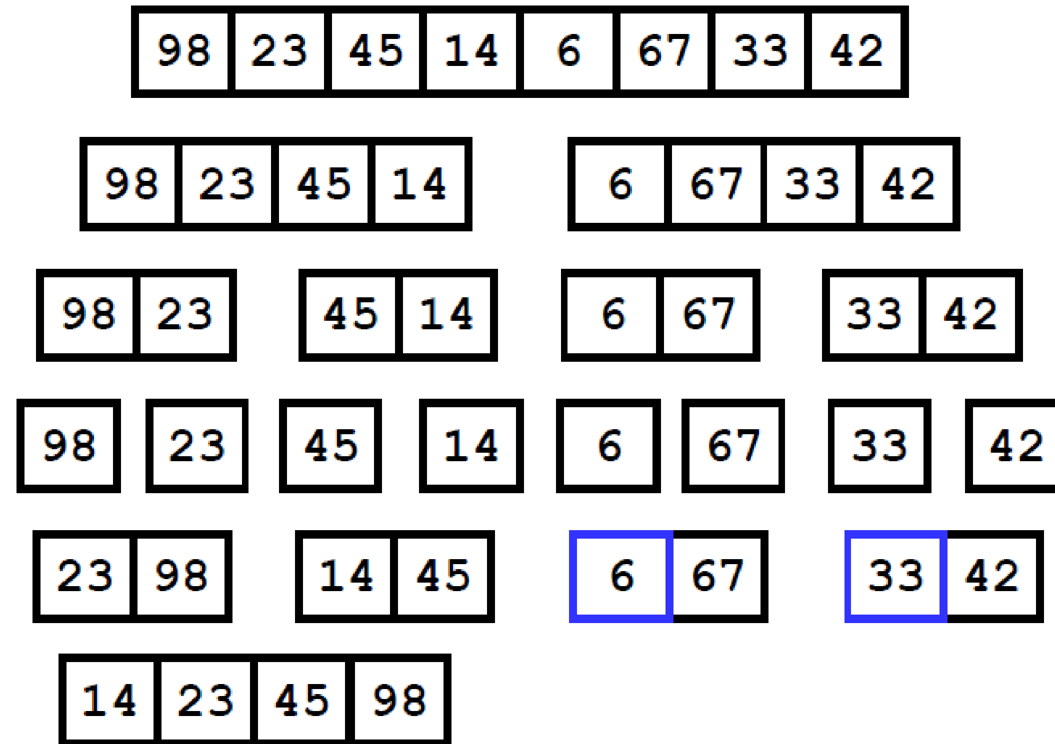

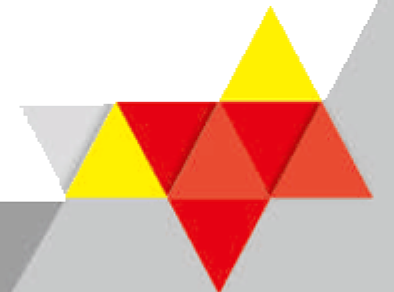

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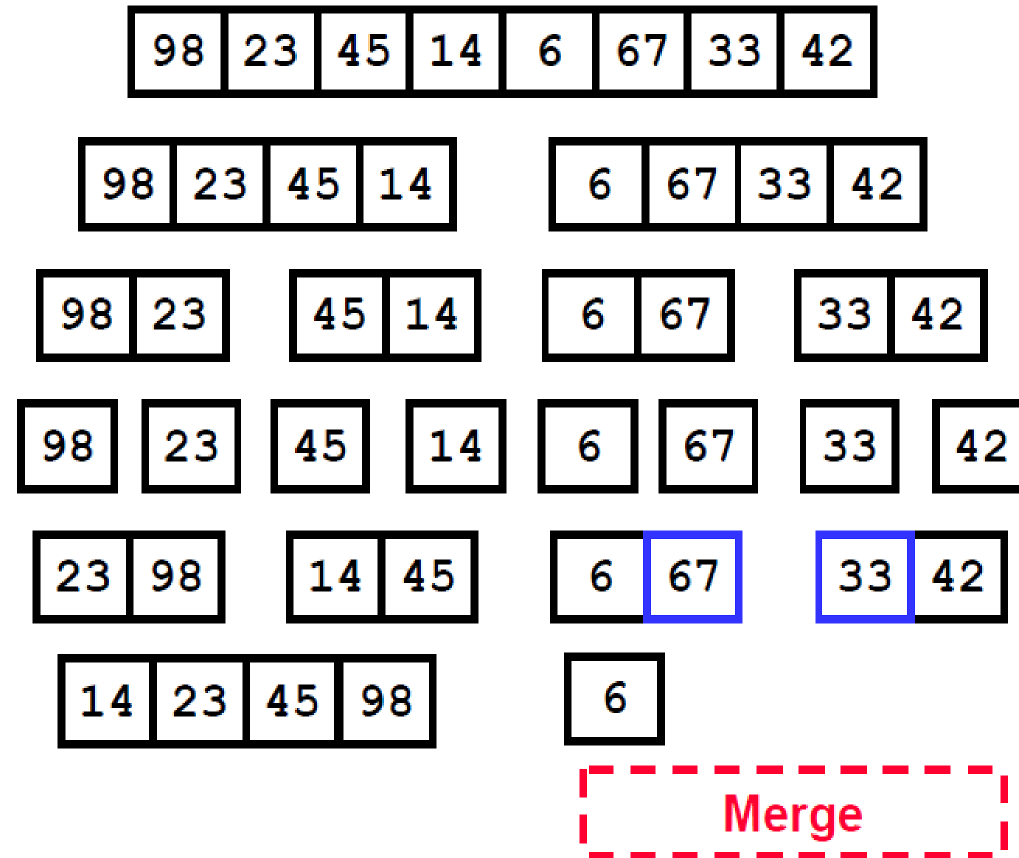

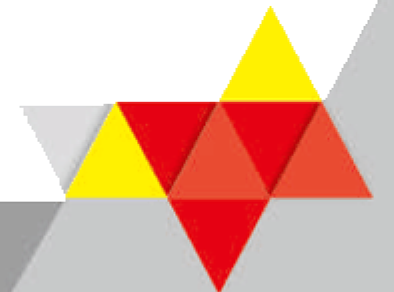

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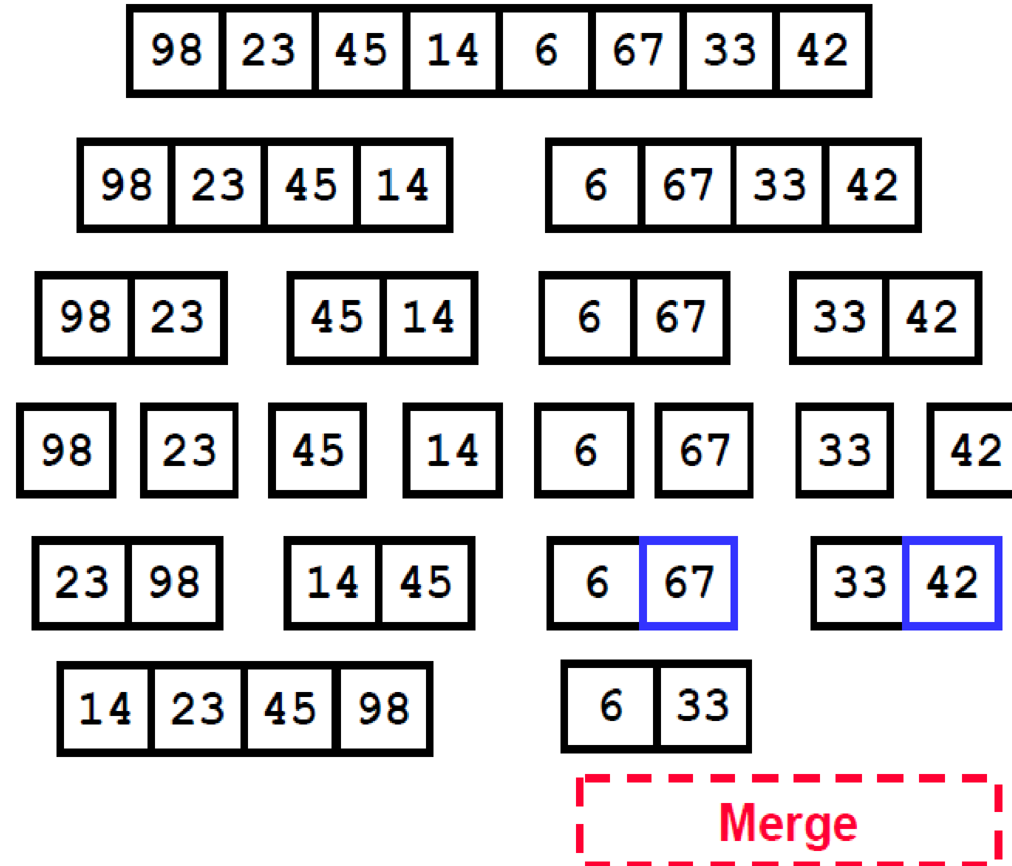
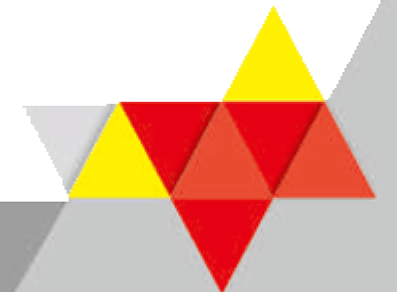
MERGE SORT





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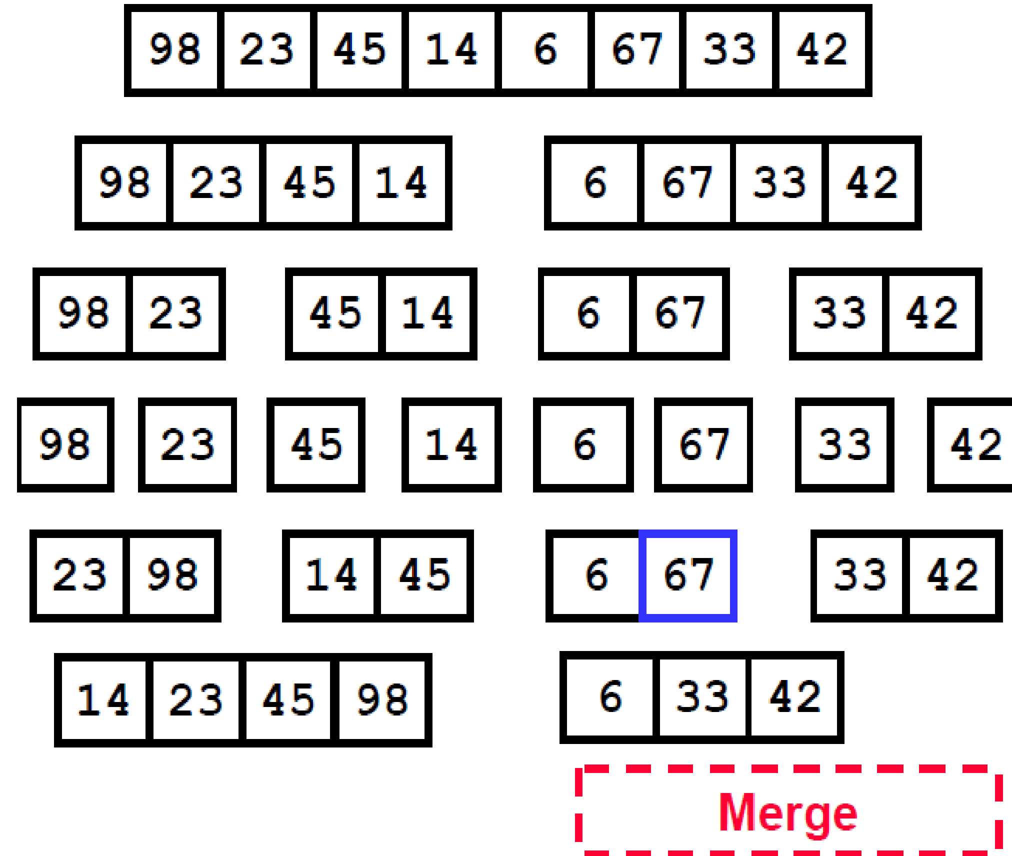

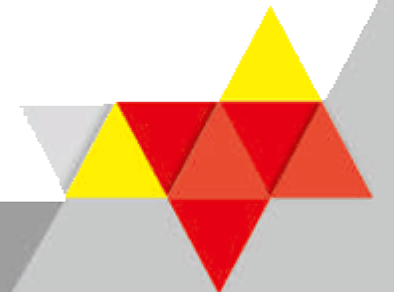

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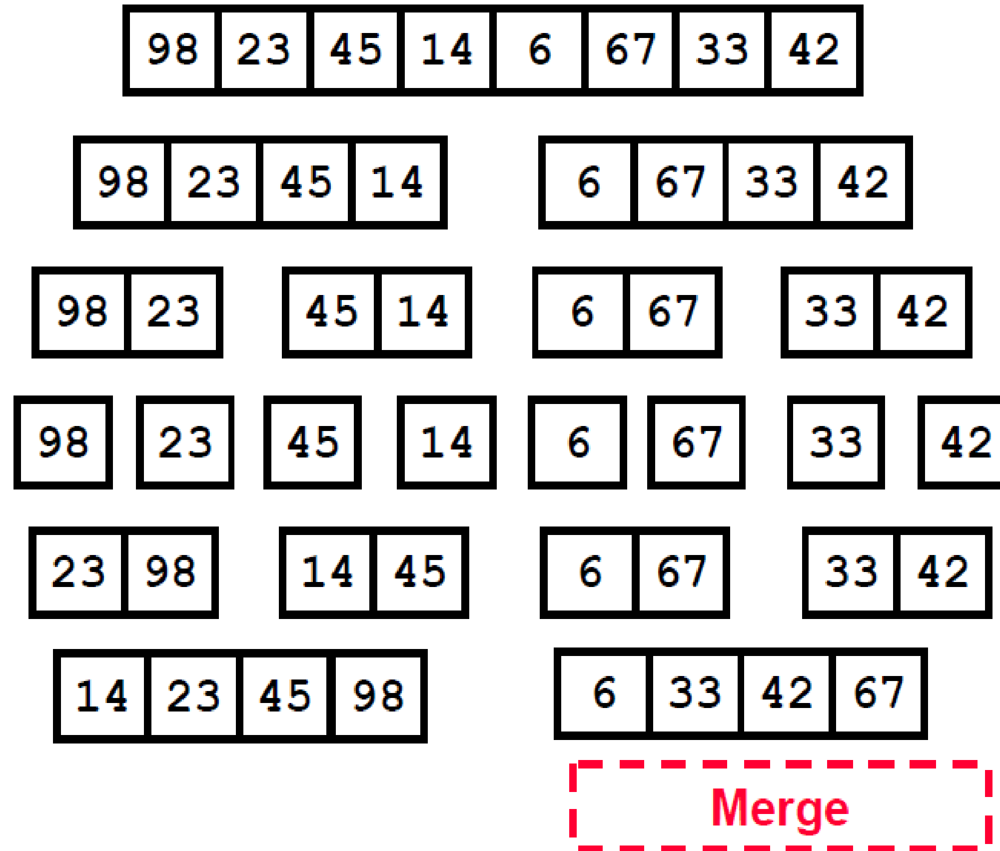

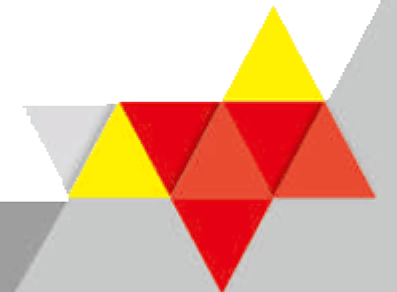

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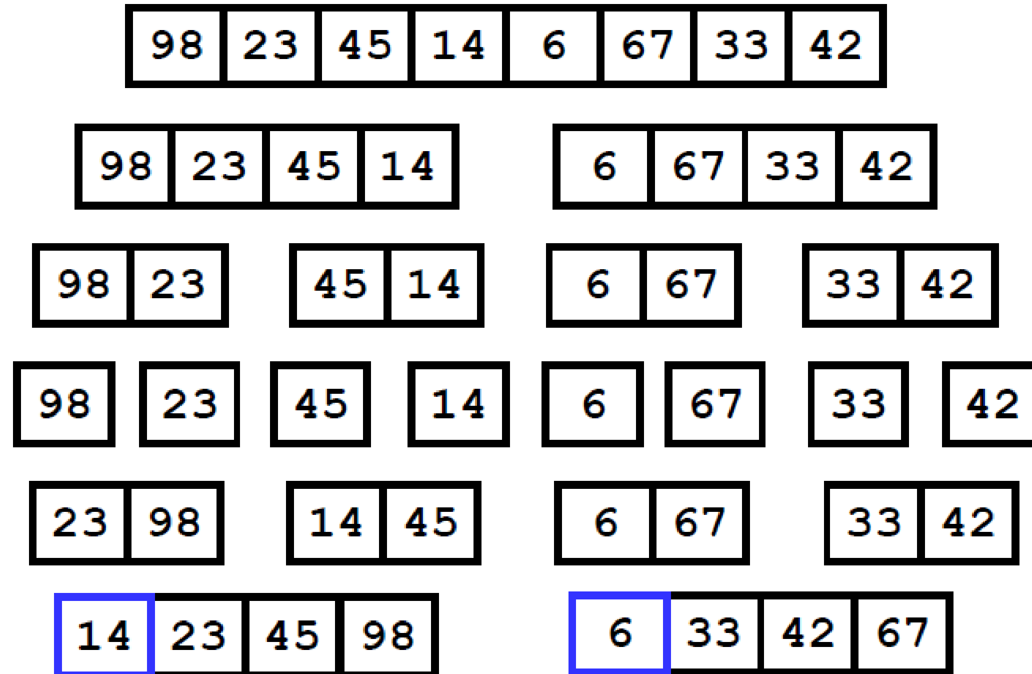

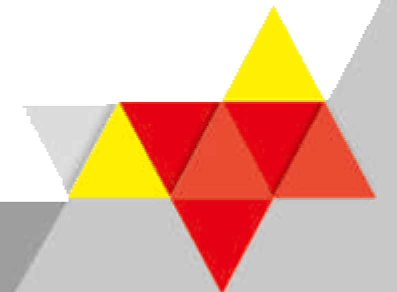

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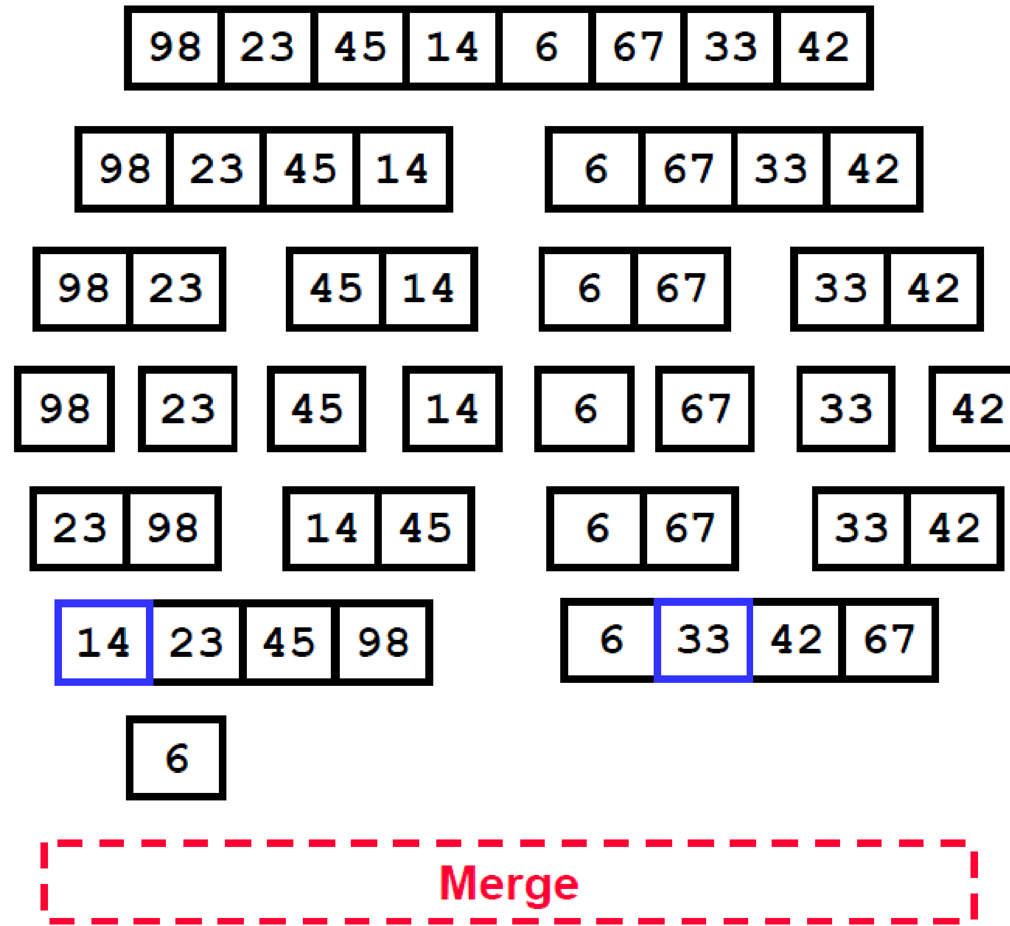
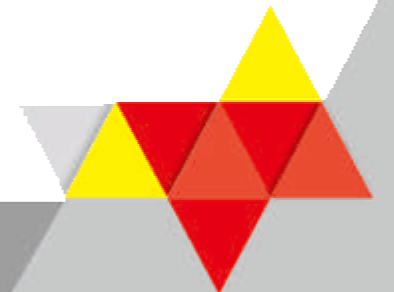
MERGE SORT





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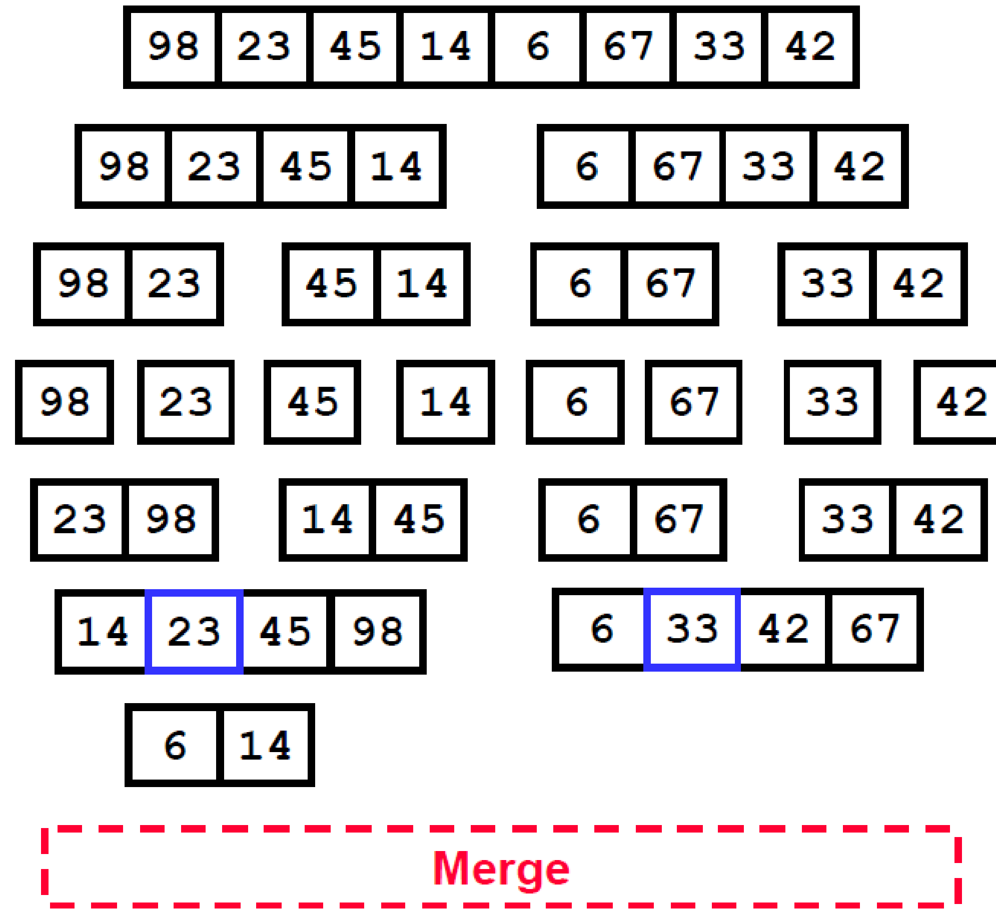

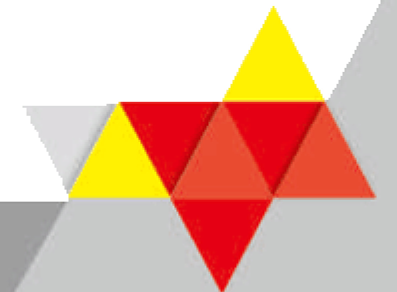

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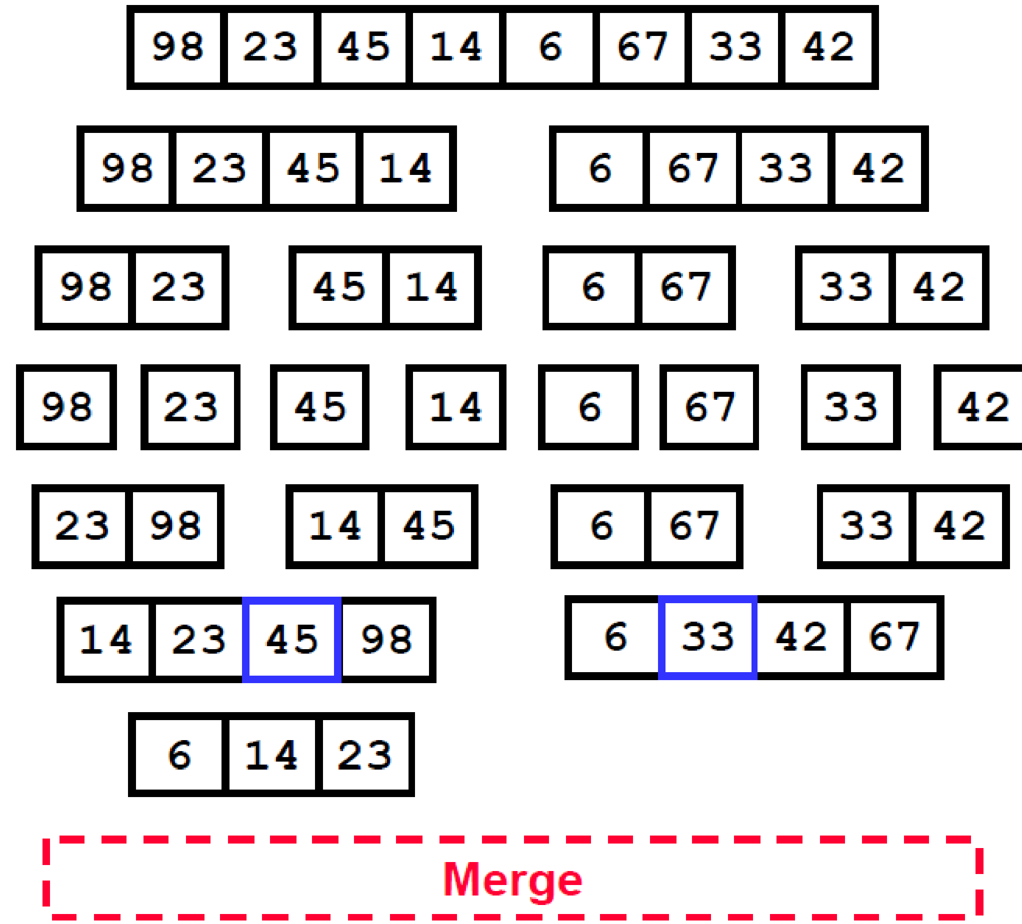

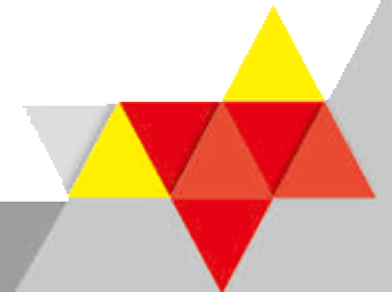

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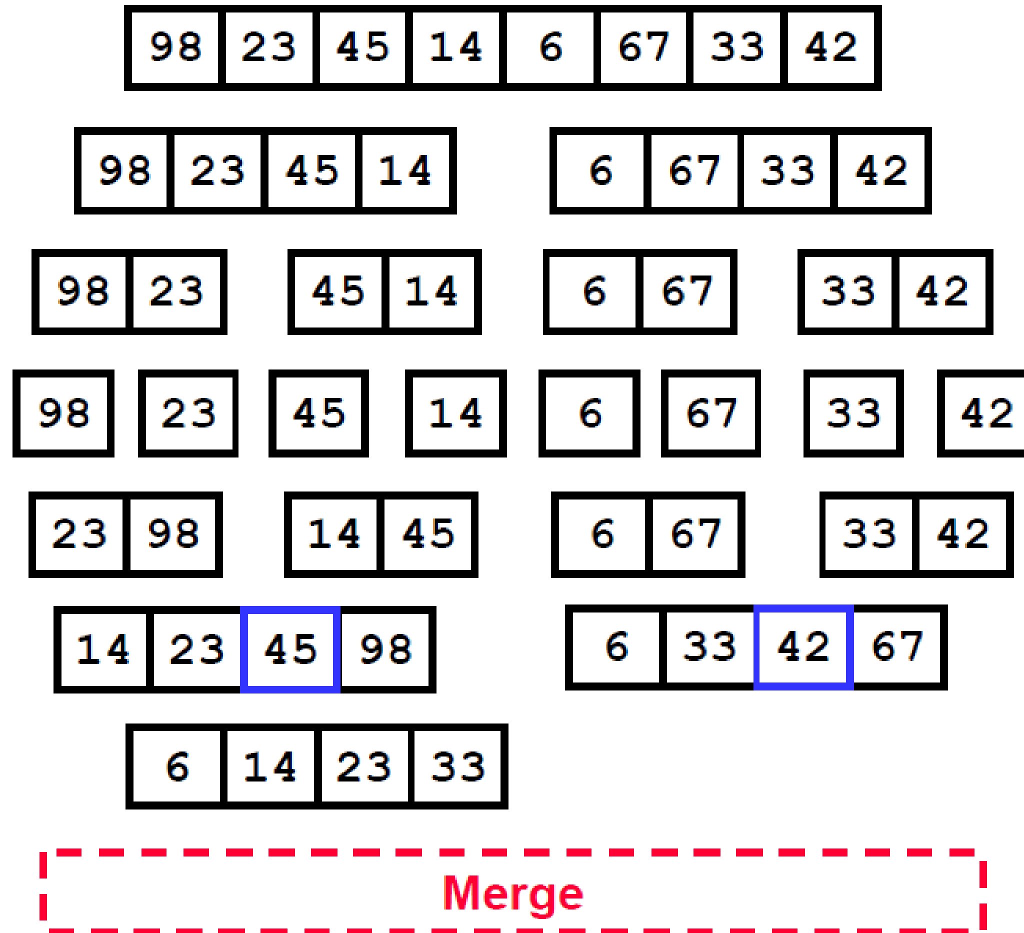

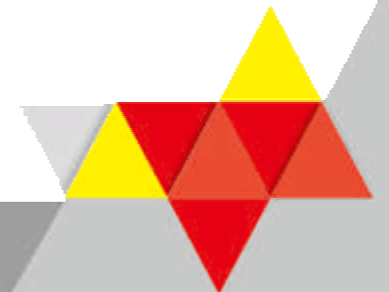

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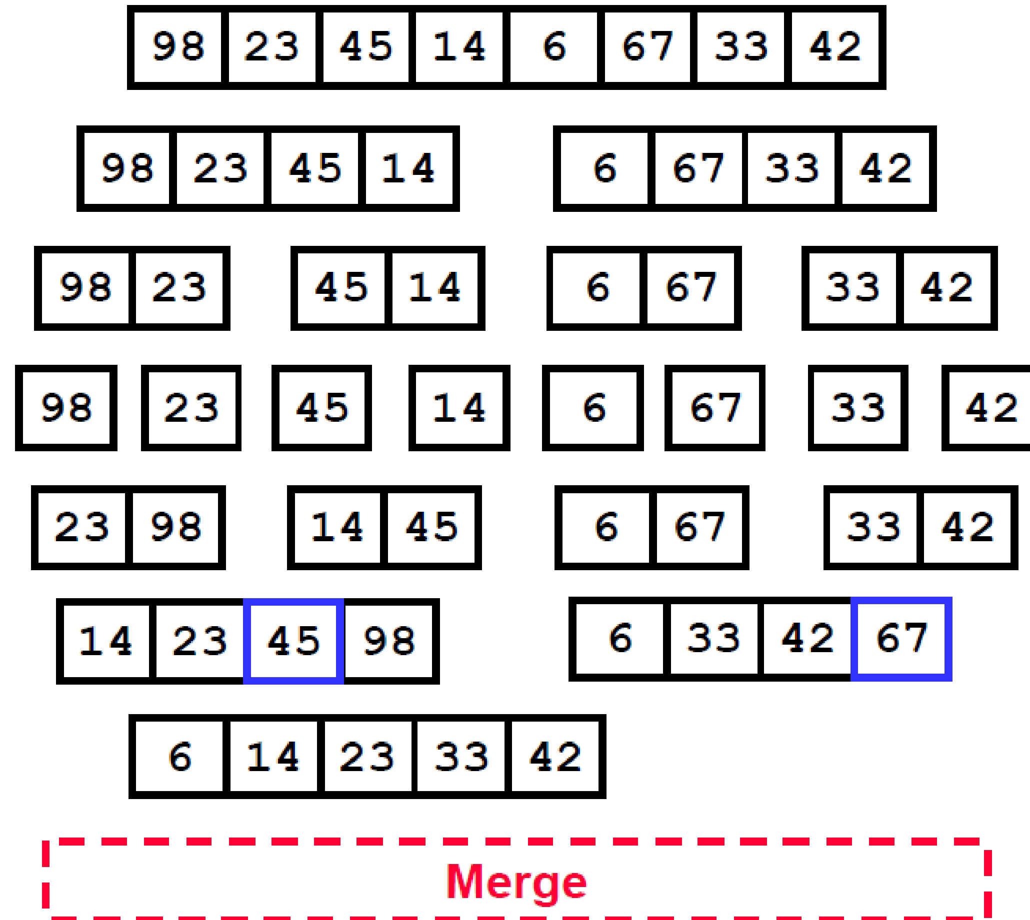

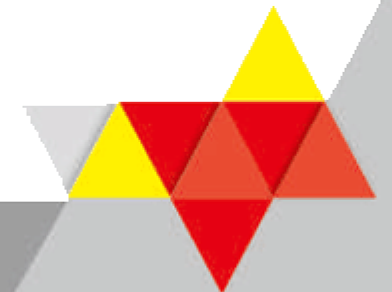

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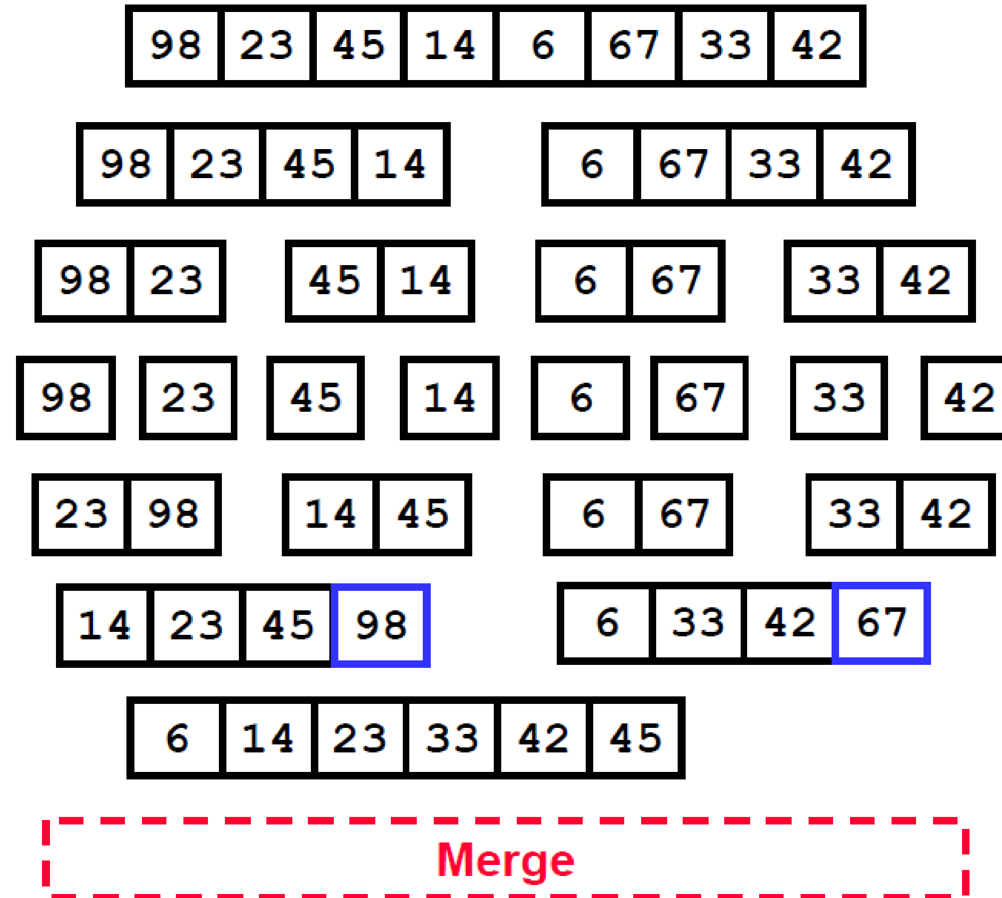
MERGE SORT



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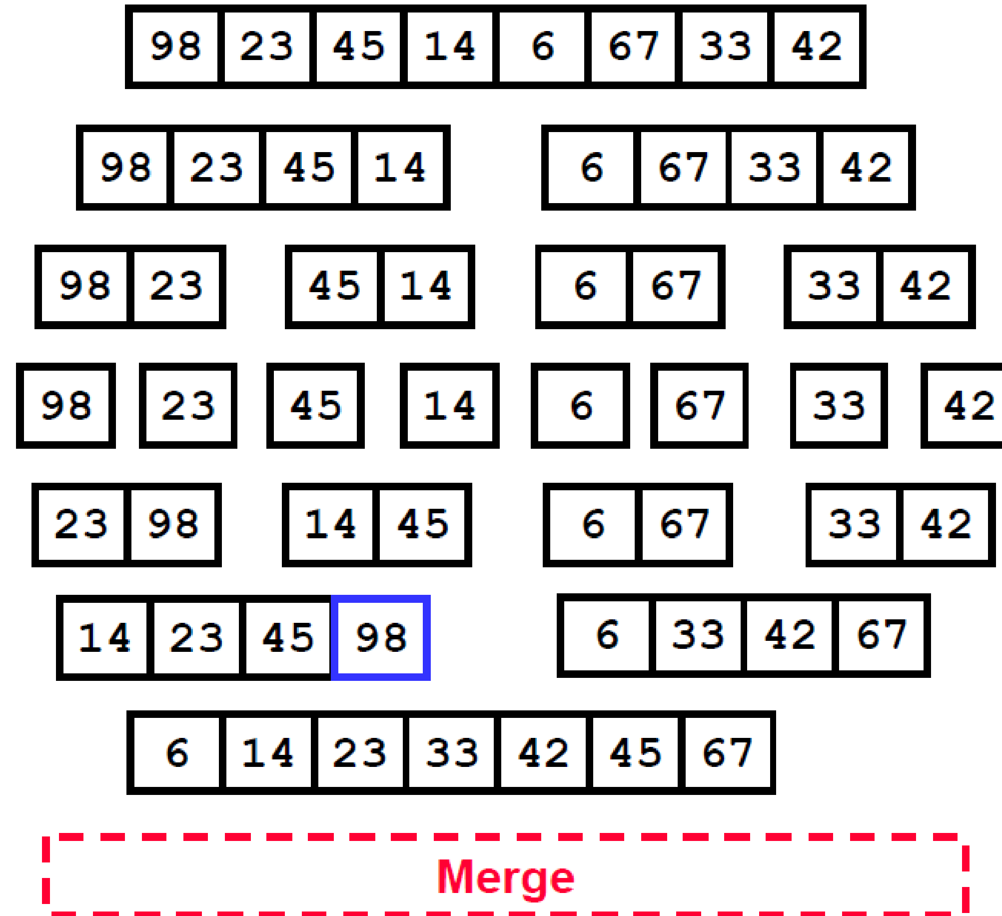

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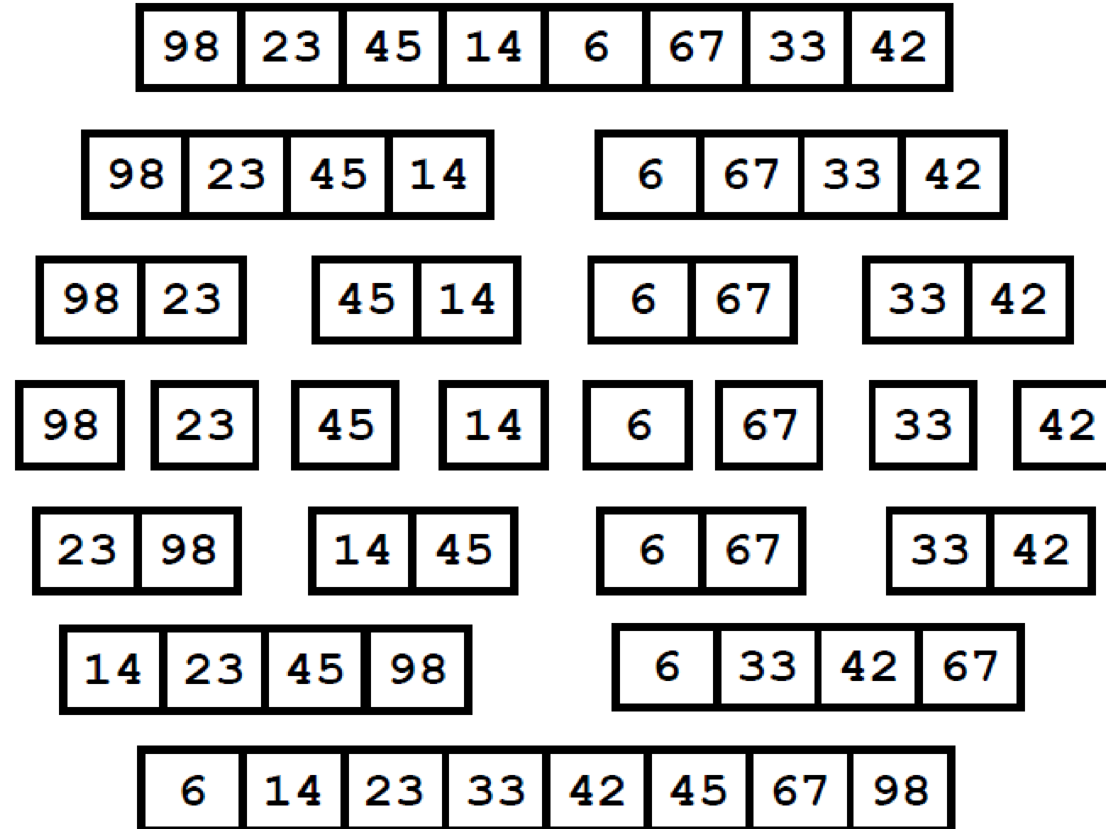
MERGE SORT



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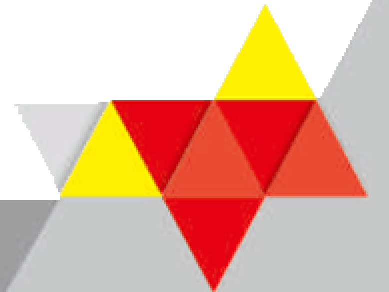
MERGE SORT

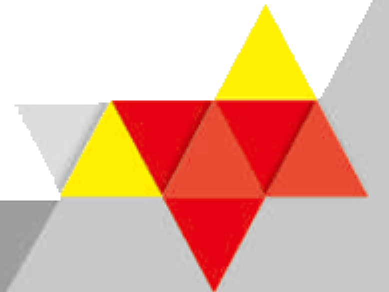
98	23	45	14	6	67	33	42

6	14	23	33	42	45	67	98



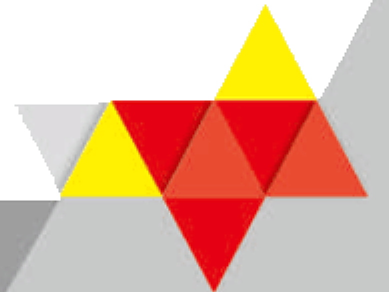
Algoritma Merge Sort

```
void MergeSortRekursif(l, r)
1. jika (l < r) maka kerjakan baris 2-5
2.          med = (l+r) / 2 ;
3.          MergeSortRekursif(l,med);
4.          MergeSortRekursif(med+1,r);
5.          Merge(l,med,r);
```



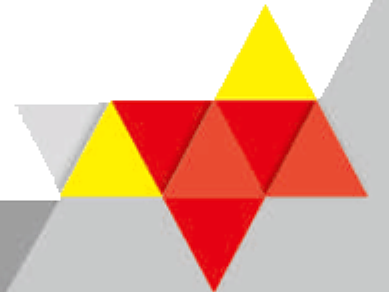
Fungsi Merge

```
void Merge(left, median, right)
1.  kiri1 ← left
2. kanan1 ← median
3. kiri2 ← median+1
4. kanan2 ← right
5. i ← left;
6. selama (kiri1<=kanan1) dan (kiri2<=kanan2) kerjakan 7-1
7.    jika (Data[kiri1] <= Data[kiri2]) kerjakan 8-9
8.           hasil[i] = Data[kiri1];
9.           kiri1++
10.   jika tidak kerjakan baris 11-12
11.          hasil[i] = Data[kiri2];
12.          kiri2++
13.    i++
```



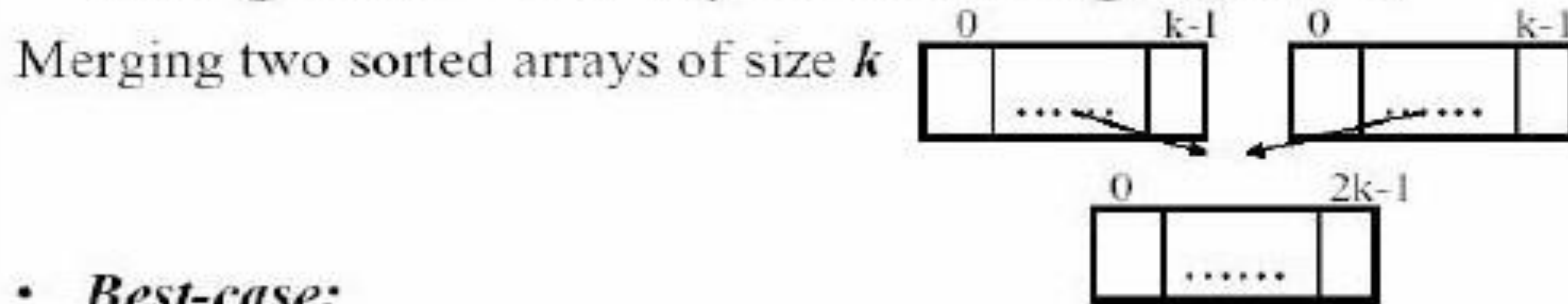
MERGE SORT

```
14. selama (kiri1<=kanan1) kerjakan baris 15-17
15.      hasil[i] = Data[kiri1]
16.      kiri1++
17.      i++

18. selama (kiri2<=kanan2) kerjakan baris 19-21
19.      hasil[i] = Data[kiri2]
20.      i++
21.      kiri2++

22.j ← left
23.selama (j <=right) kerjakan baris 24-25
24.      Data[j] = hasil[j]
25.      j++
```

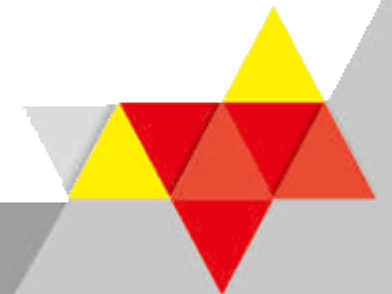


Mergesort – Analysis of Merge (cont.)

Merging two sorted arrays of size ***k***

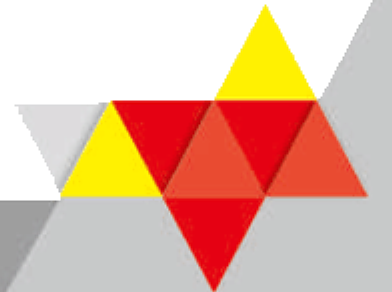


- ***Best-case:***
  - All the elements in the first array are smaller (or larger) than all the elements in the second array.
  - The number of moves: 2k + 2k
  - The number of key comparisons: k
- ***Worst-case:***
  - The number of moves: 2k + 2k
  - The number of key comparisons: 2k-1

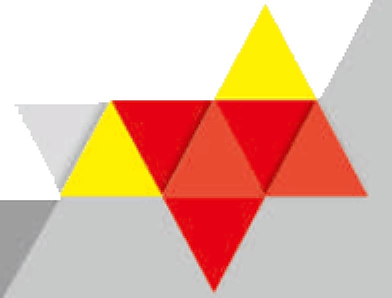


Summary

- **Divide the unsorted collection into two**
- **Until the sub-arrays only contain one element**
- **Then merge the sub-problem solutions together**



4. QUICK SORT



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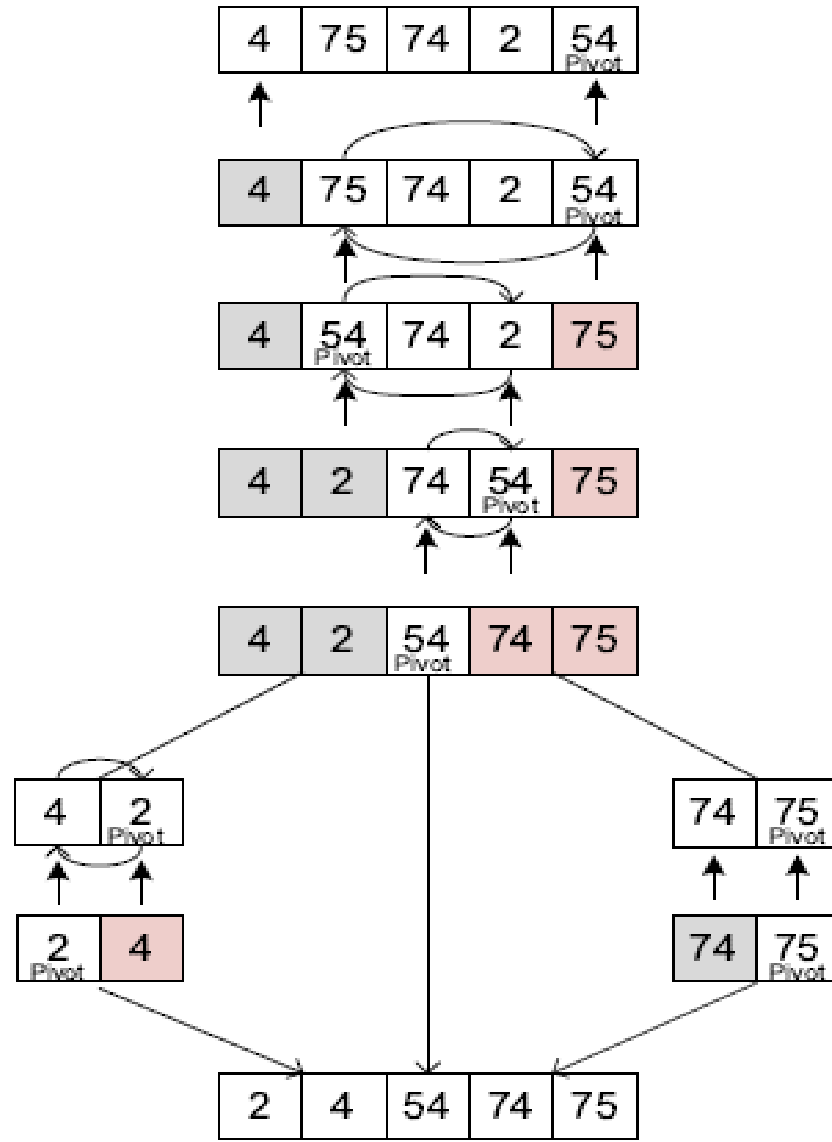
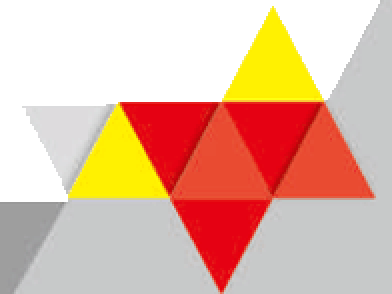
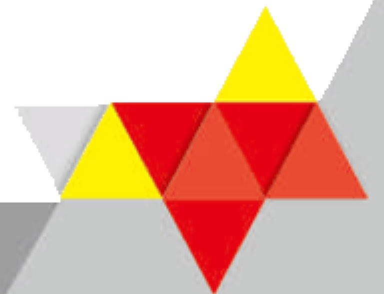
QUICK SORT



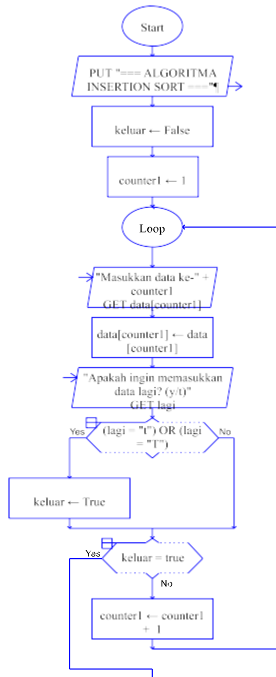


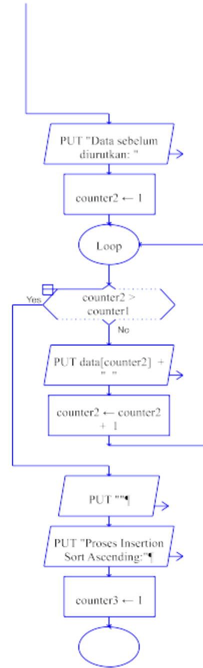
QUICK SORT

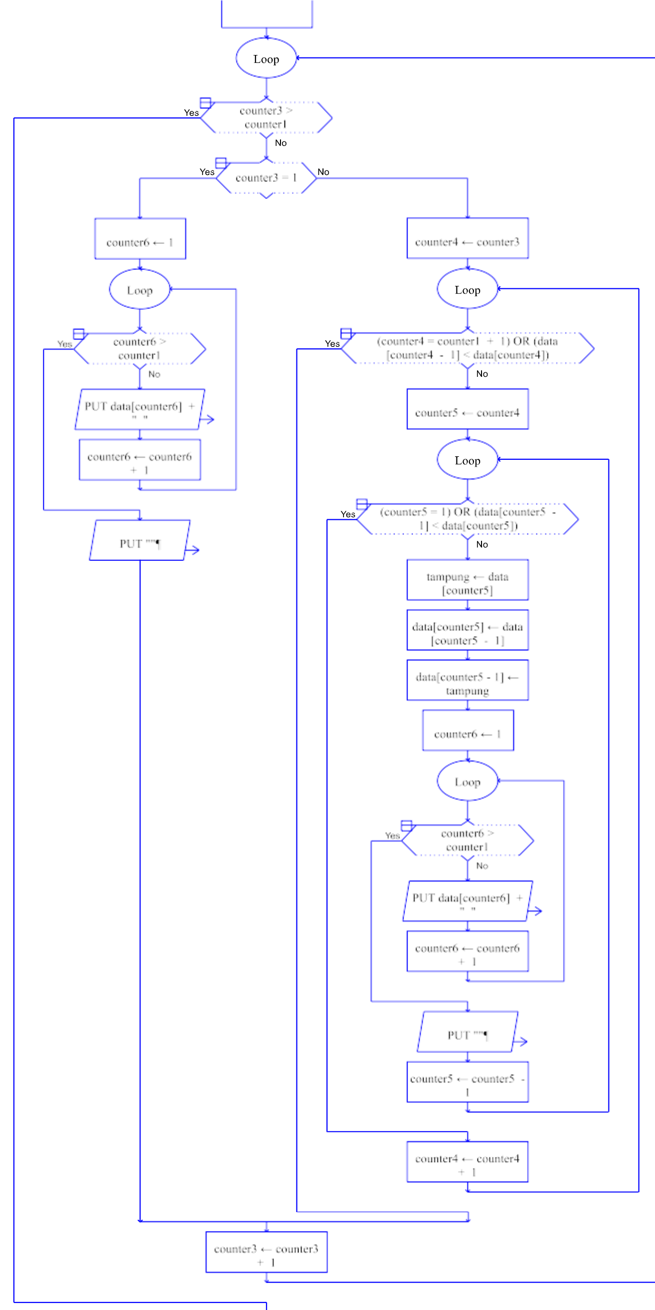
```
1) algorithm QuickSort(list)
2)     Pre:  list ≠ ∅
3)     Post: list has been sorted into values of ascending order
4)     if list.Count = 1 // already sorted
5)        return list
6)     end if
7)     pivot ← MedianValue(list)
8)     for i ← 0 to list.Count−1
9)        if list[i] = pivot
10)          equal.Insert(list[i])
11)       end if
12)       if list[i] < pivot
13)          less.Insert(list[i])
14)       end if
15)       if list[i] > pivot
16)          greater.Insert(list[i])
17)       end if
18)    end for
19)    return Concatenate(QuickSort(less), equal, QuickSort(greater))
20) end Quicksort
```

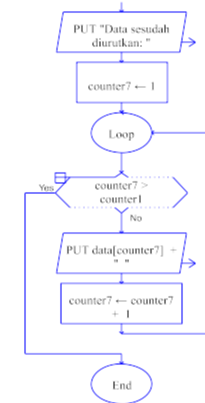


QUICK SORT ASCENDING









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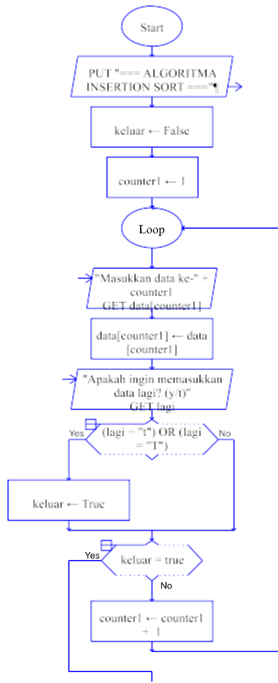
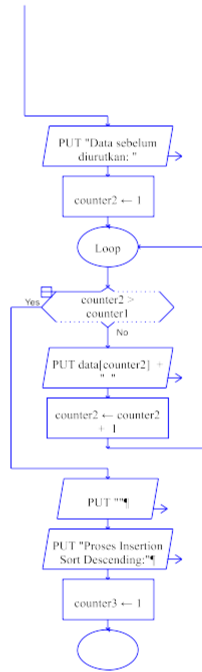
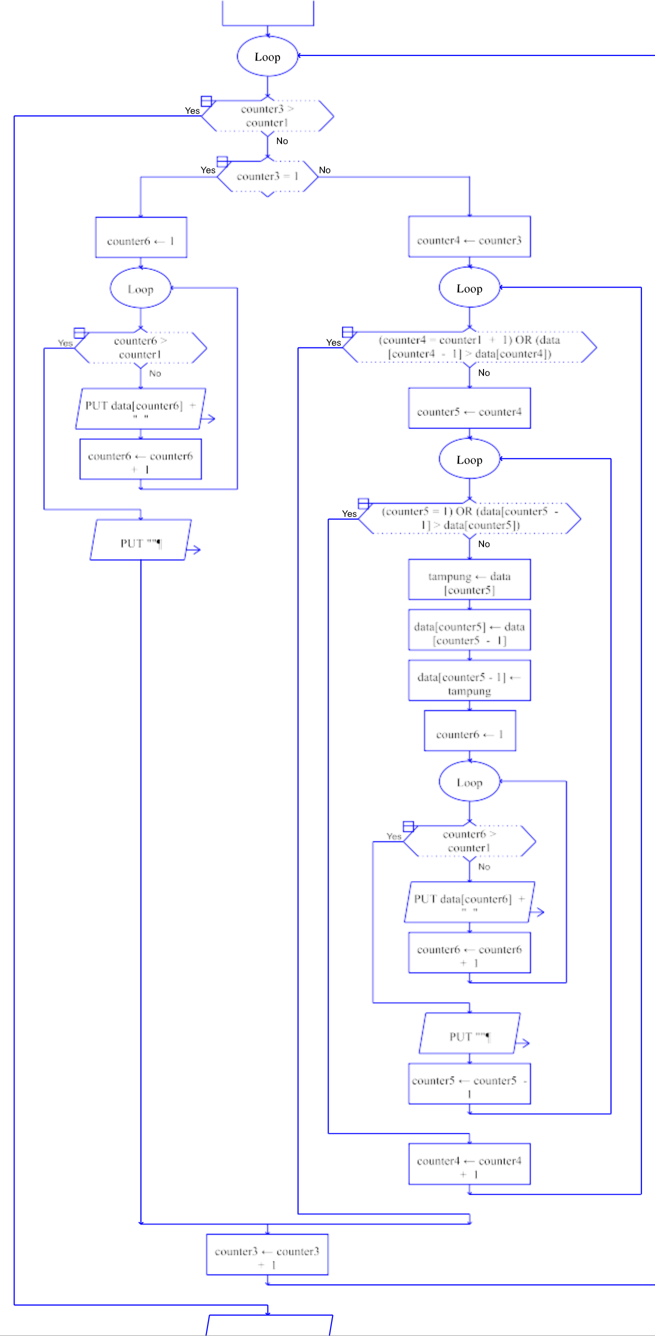
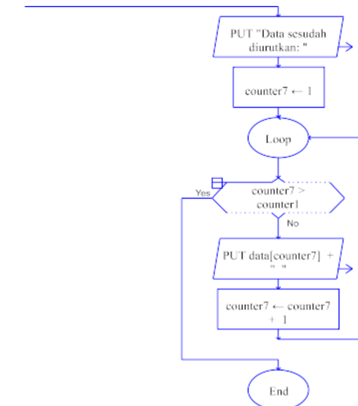
QUICK SORT DESCENDING









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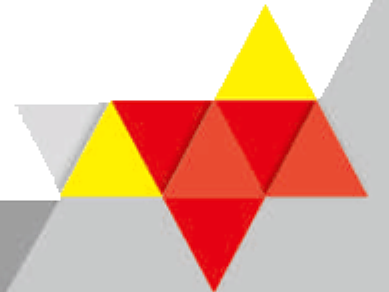
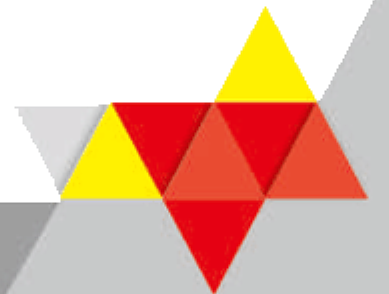
5. INSERTION SORT



INSERTION SORT

- Metode Penyisipan
- Insertion sort menjadikan bagian kiri dari array terurut sampai keseluruhan dari array terurut.
- Algoritma ini diawali dengan membaca nilai-nilai di sebelah kanan dan membandingkan nilai-nilai di sebelah kiri, setelah ketemu tempatnya maka nilai yang dibaca ini disisipkan.



INSERTION SORT

3	10	4	6	8	9	7	2	1	5

Nilai paling kiri(3) dapat dikatakan diurutkan dengan dirinya sendiri. Sehingga, kita tidak butuh untuk melakukan sesuatu terhadap nilai ini.

INSERTION SORT

3	10	4	6	8	9	7	2	1	5

3	10	4	6	8	9	7	2	1	5

Cek dan lihat nilai kedua(10) apakah lebih kecil dari nilai pertama(3). Jika ya, tukar kedua nilai tersebut. Akan tetapi dalam hal ini kita tidak menukarnya.

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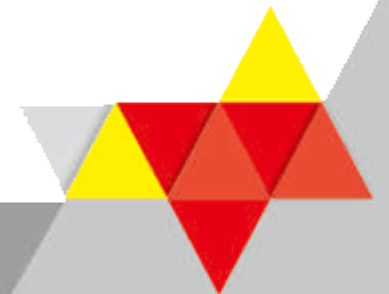
INSERTION SORT

3	10	4	6	8	9	7	2	1	5

Angka biru/wilayah abu-abu (dua nilai pertama) secara relatif sudah dalam kondisi terurut.

3	10	4	6	8	9	7	2	1	5

Selanjutnya, kita butuh menyisipkan nilai ketiga(4) dalam daerah abu-abu agar setelah penyisipan, daerah abu-abu tetap secara relatif dalam kondisi terurut.



INSERTION SORT

Pertama : Simpan nilai ketiga dalam sebuah variabel.

4

3	10		6	8	9	7	2	1	5

Kedua : Lihat nilai di sebelah kirinya (10), jika lebih besar geser ke kanan. Langkah ini diulang sampai ditemukan nilai lebih kecil.

4

3		10	6	8	9	7	2	1	5

Ketiga : Sisipkan nilai 4 pada posisi yang sesuai.

3	4	10	6	8	9	7	2	1	5

INSERTION SORT

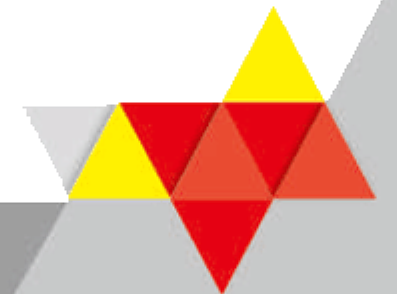
Sekarang ketiga nilai pertama secara relatif dalam kondisi terurut, dan kita telah menyisipkan nilai keempat dalam ketiga nilai tsb, sehingga keempat nilai pertama secara relatif telah terurut.

3	4	6	10	8	9	7	2	1	5

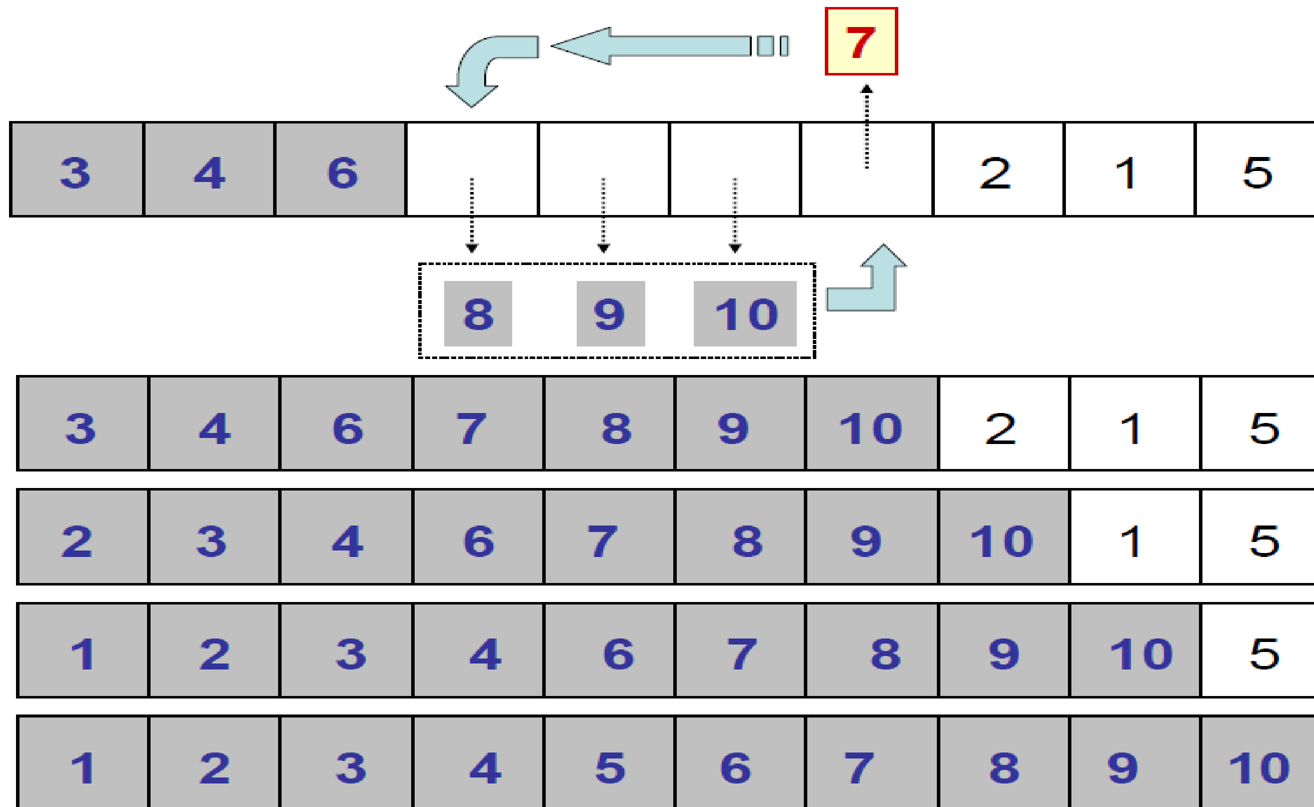
Ulangi proses sampai nilai terakhir telah disisipkan.

3	4	6	8	10	9	7	2	1	5

3	4	6	8	9	10	7	2	1	5

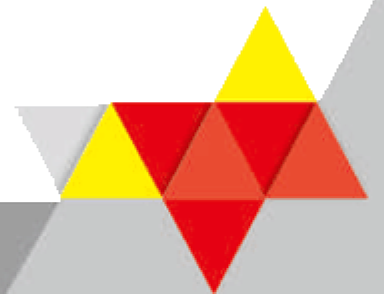


INSERTION SORT



Algoritma

1. Ulangi langkah 2-6 untuk j=1 s/d n-1
2. i <- j – 1
3. tmp <- data[j]
4. Ulangi langkah 5-6 selama i>=0 dan tmp<data[i]
5. data[i+1]=data[i]
6. i--
7. data[i+1]=tmp



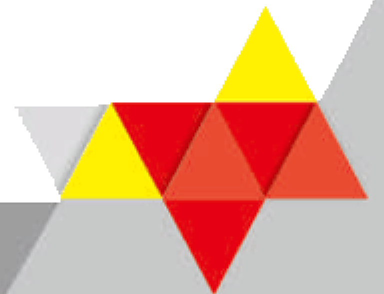
Insertion Sort → Analysis

- Assuming there are n elements in the array, we must index through n - 1 entries.
- For each entry, we may need to examine and shift up to n - 1 other entries, resulting in a $\boldsymbol{O}(n^2)$ algorithm.
- The insertion sort is an *in-place* sort. That is, we sort the array in-place. No extra memory is required.
- The insertion sort is also a *stable* sort. Stable sorts retain the original ordering of keys when identical keys are present in the input data.

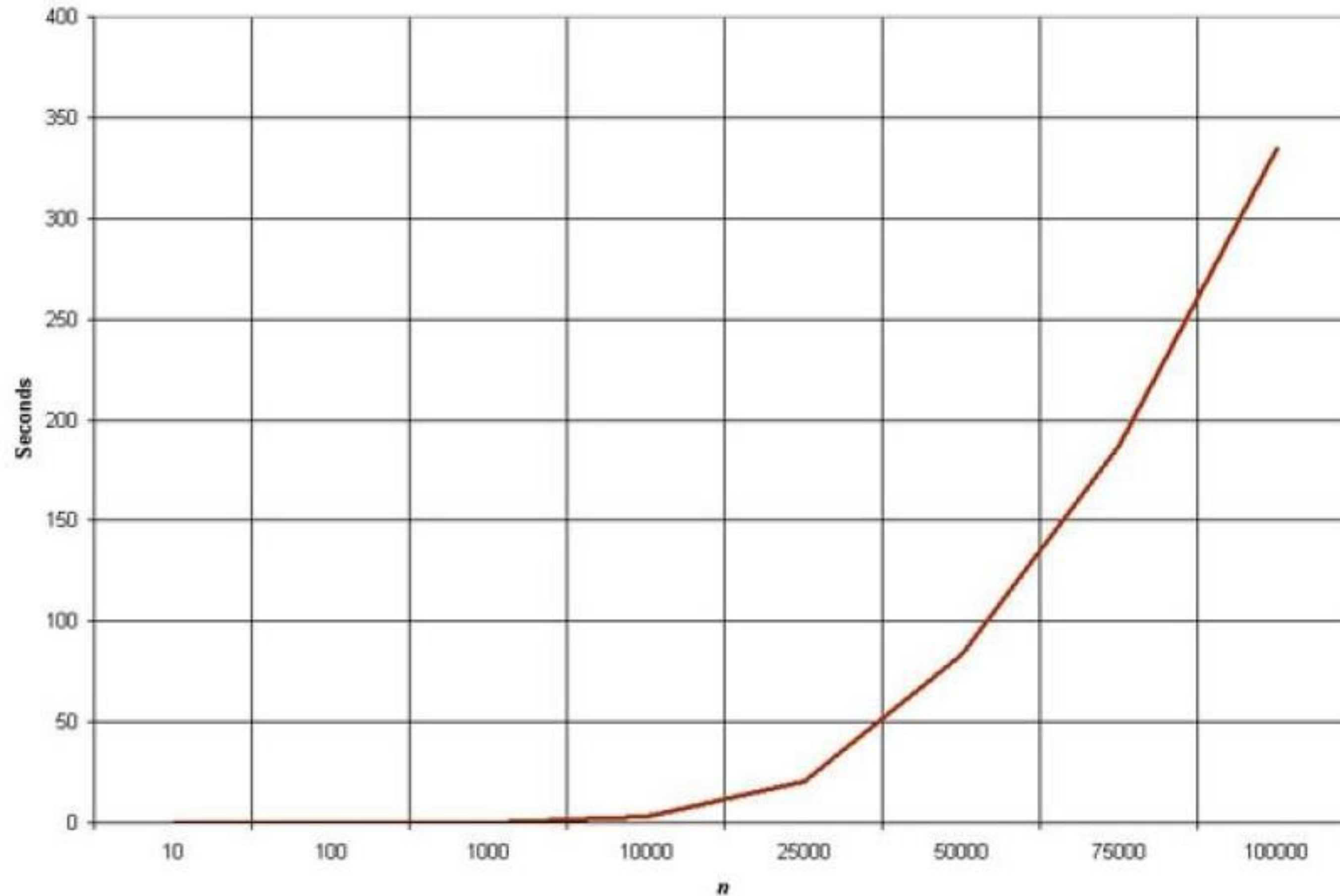
INSERTION SORT

Insertion Sort → Analysis

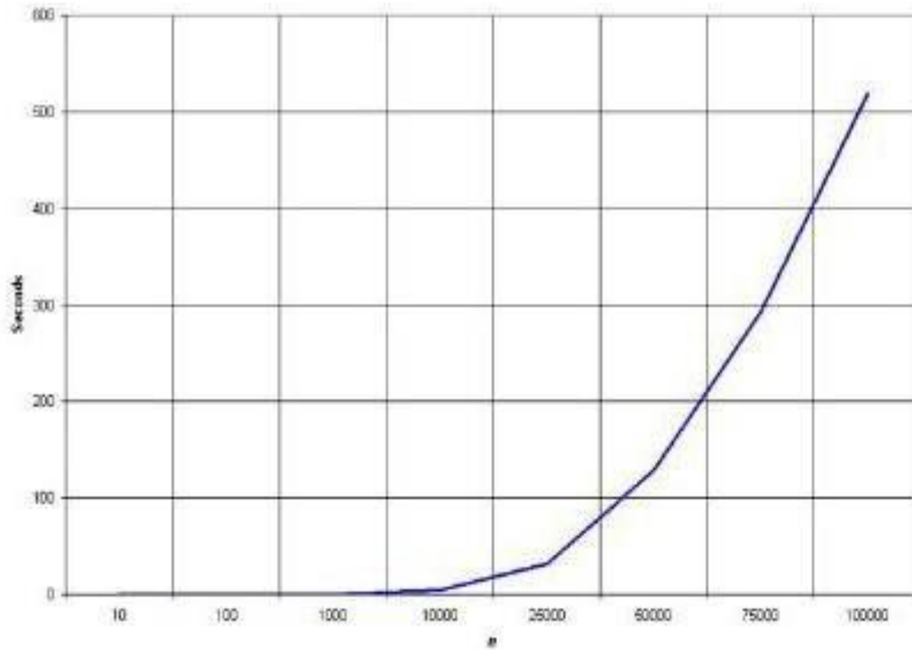
- **best case:**
  - about N comparisons, 0 moves, (input already sorted)
- **worst case:**
  - about $N^2/2$ comparisons, $N^2/2$ moves, (input sorted in reverse order)
- **average case:**
  - about $N^2/4$ comparisons, $N^2/4$ moves
- **notes:**
  - very efficient when input is "almost sorted";
  - moving a record is about half the work of exchanging two records, so average case is equivalent to roughly $N^2/8$ exchanges.

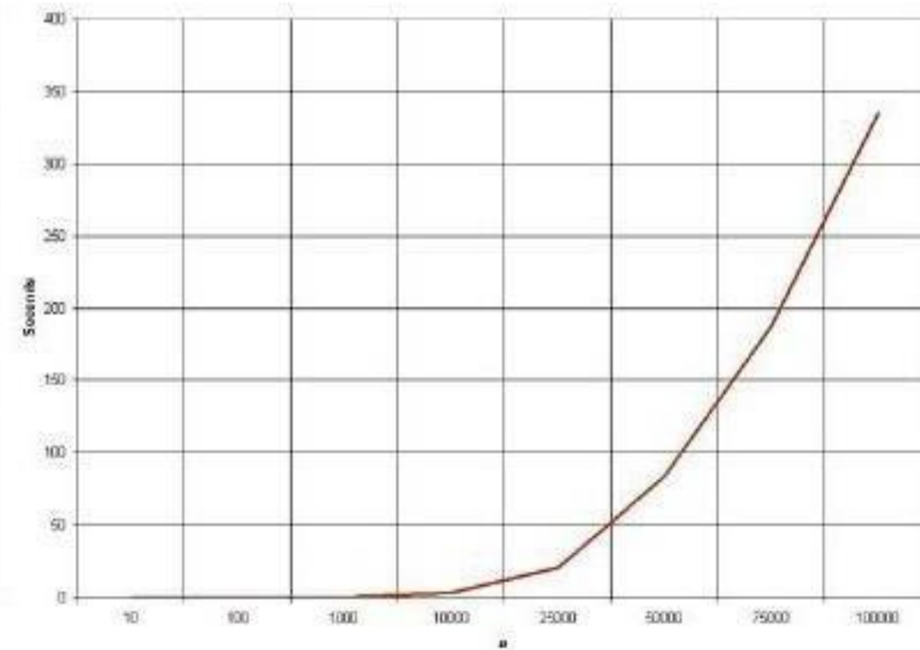


INSERTION SORT

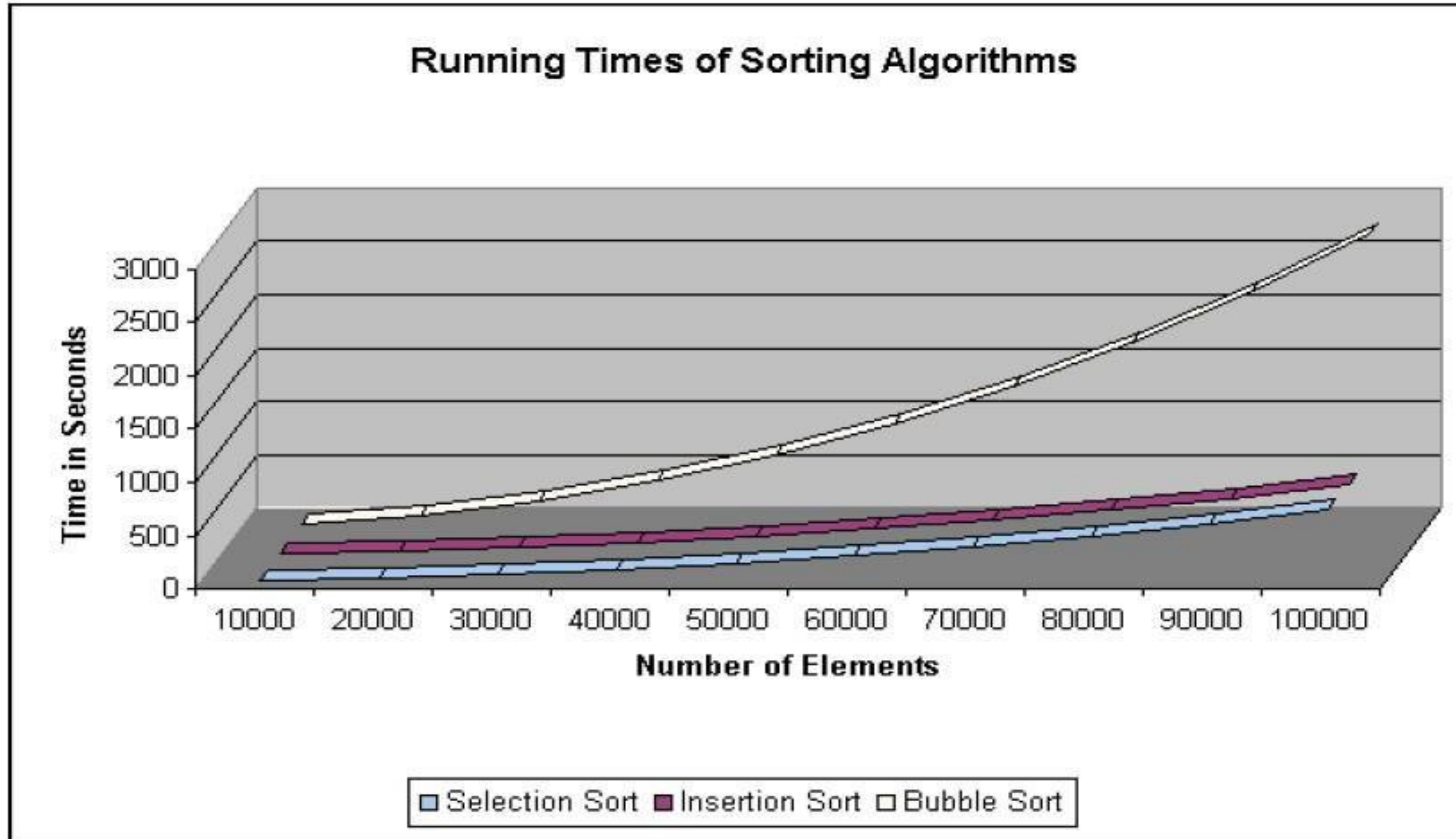


INSERTION SORT

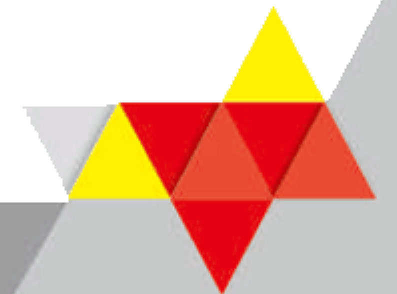




INSERTION SORT



Selection Sort yields a 60% performance improvement over the Bubble Sort



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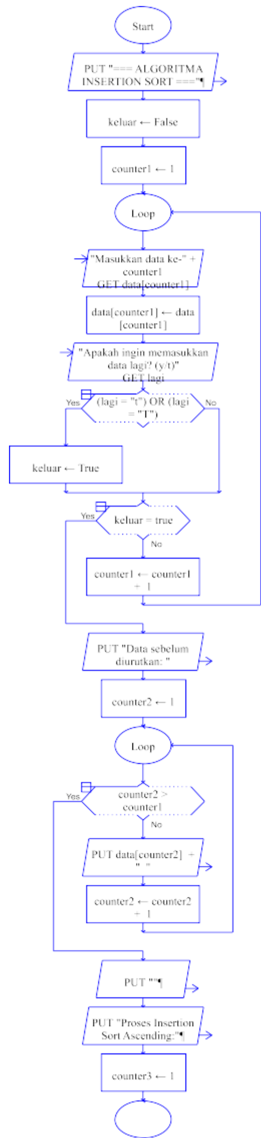
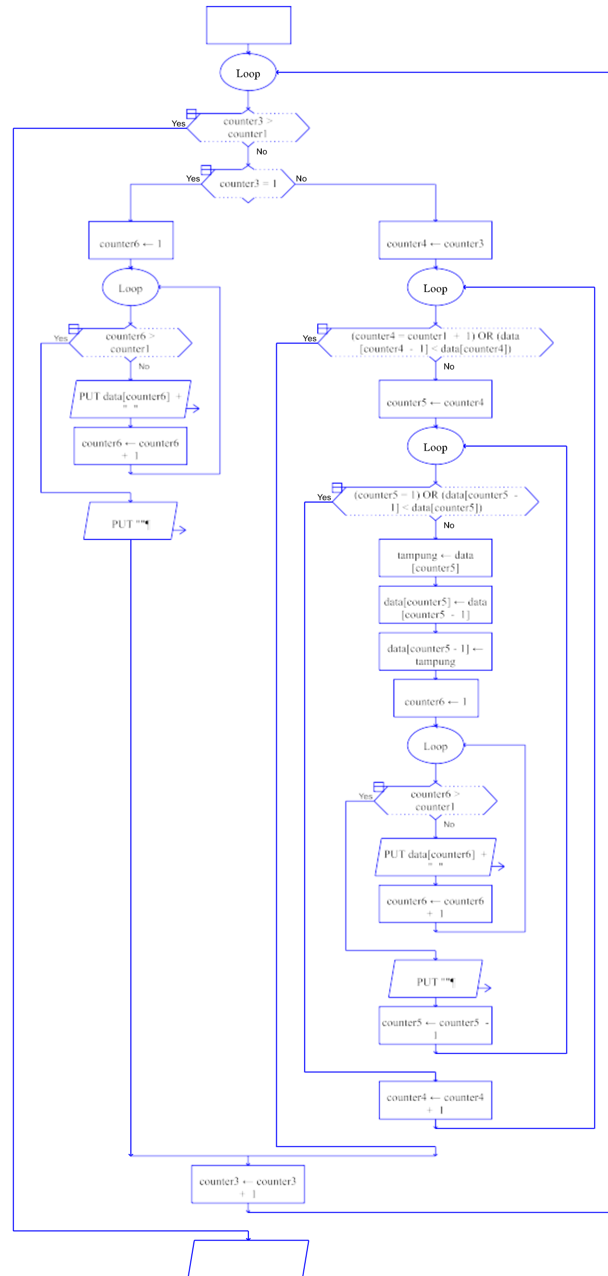
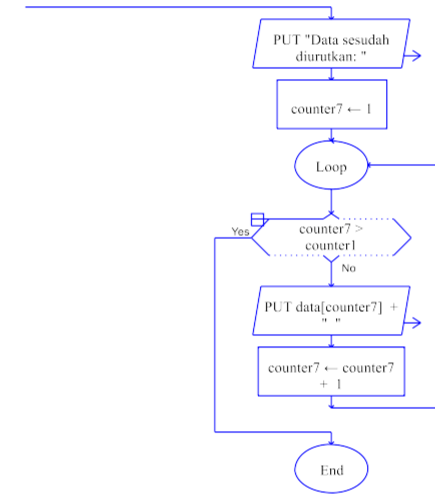
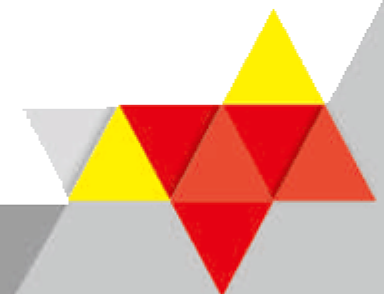
INSERTION SORT ASCENDING









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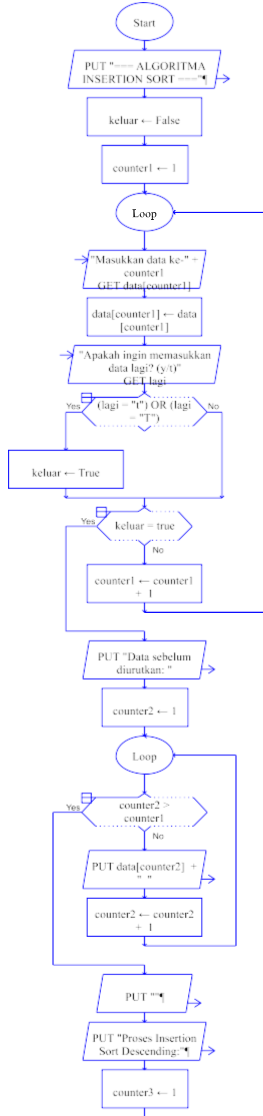
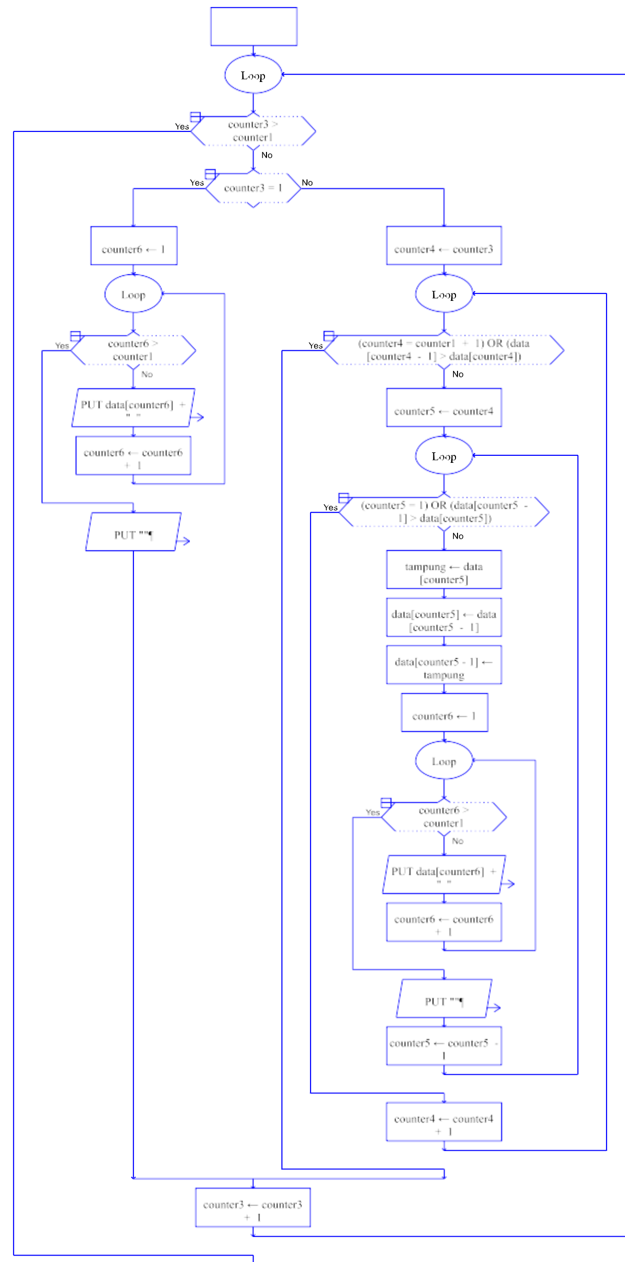
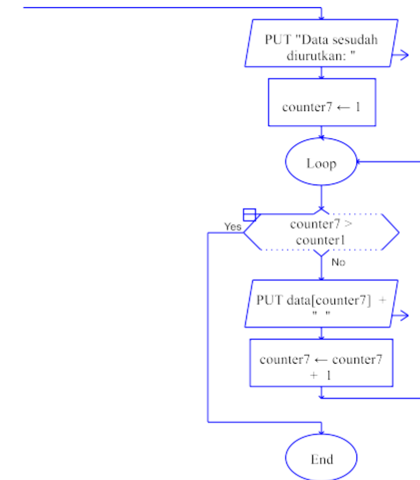
INSERTION SORT DESCENDING







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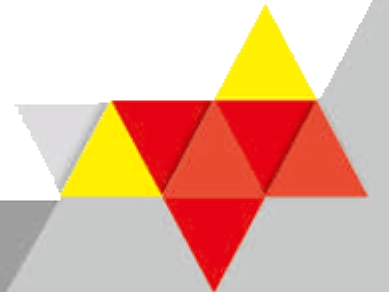
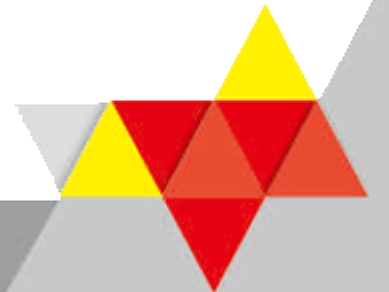
PERBANDINGAN SORTING

- Bubble sort uses about $N^2/2$ comparisons and $N^2/2$ exchanges on the average and in the worst case.
- Selection sort uses about $N^2/2$ comparisons and N exchanges on the average, twice as many in the worst case.
- Insertion sort uses about $N^2/4$ comparisons and $N^2/8$ exchanges and is linear for "almost sorted" files.

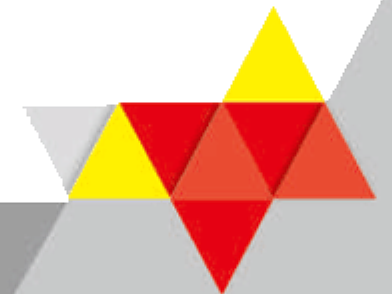


6. SHELL SORT



SHELL SORT

- Metode ini disebut juga dengan metode pertambahan menurun *(diminishing increment sort)*. Metode ini dikembangkan oleh Donald L. Shell pada tahun 1959, sehingga sering disebut dengan Metode Shell Sort.
- Metode ini mengurutkan data dengan cara membandingkan suatu data dengan data lain yang memiliki jarak tertentu – sehingga membentuk sebuah sub-list-, kemudian dilakukan penukaran bila diperlukan



SHELL SORT

- Jarak yang dipakai didasarkan pada *increment value* atau *sequence number* k
- Misalnya Sequence number yang dipakai adalah 5,3,1. Tidak ada pembuktian di sini bahwa bilangan-bilangan tersebut adalah sequence number terbaik
- Setiap sub-list berisi setiap elemen ke-k dari kumpulan elemen yang asli

SHELL SORT

- Contoh: Jika k = 5 maka sub-list nya adalah sebagai berikut :

  - s[0] s[5] s[10] ...

  - s[1] s[6] s[11] ...

  - s[2] s[7] s[12] ...

  - dst

- Begitu juga jika k = 3 maka sub-list nya adalah:

  - s[0] s[3] s[6] ...

  - s[1] s[4] s[7] ...

  - dst

SHELL SORT

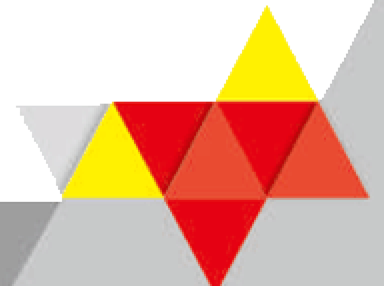
- Buatlah sub-list yang didasarkan pada jarak (Sequence number) yang dipilih
- Urutkan masing-masing sub-list tersebut
- Gabungkan seluruh sub-list

Let's see this algorithm in action

SHELL SORT

- Urutkan sekumpulan elemen di bawah ini , misalnya diberikan sequence number : 5, 3, 1

30	62	53	42	17	97	91	38
[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]



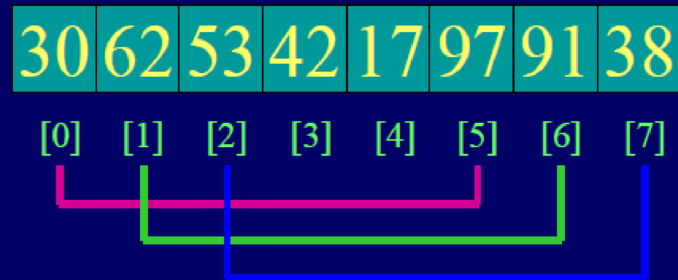
SHELL SORT

Proses Shell Sort k=5

30 62 53 42 17 97 91 38

Step 1: Buat sub list k = 5

S[0] S[5]
S[1] S[6]
S[2] S[7]
S[3]



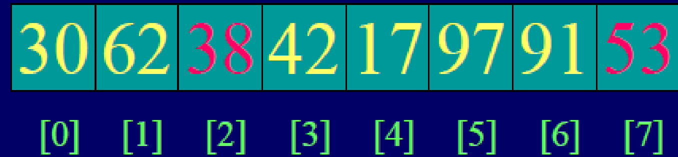
Step 2 - 3: Urutkan sub list & gabungkan

S[0] < S[5] **30, 97 OK**

S[1] < S[6] **62, 91 OK**

S[2] > S[7] **53, 38 not OK.**

Swap them **38, 53**



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SHELL SORT

Proses Shell Sort utk k=3

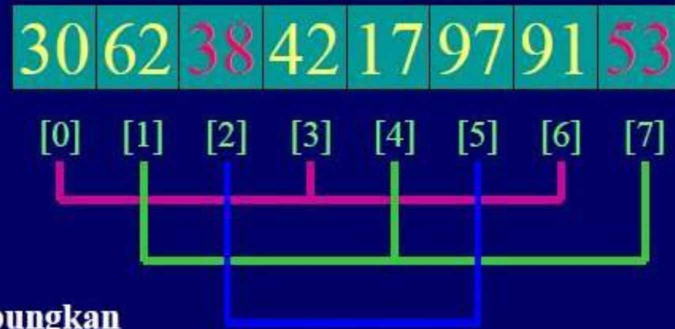
30 62 53 42 17 97 91 38

Step 1: Buat sub list k = 3

S[0] S[3] S[6]

S[1] S[4] S[7]

S[2] S[5]



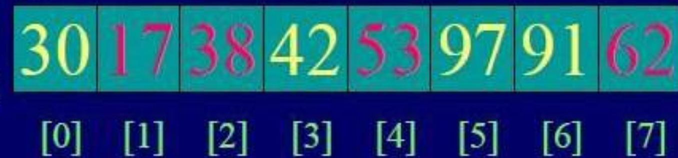
Step 2 - 3: Urutkan sub list & gabungkan

S[0] S[3] S[6] **30, 42, 91 OK**

S[1] S[4] S[7] **62, 17, 53 not OK**

SORT them **17, 53, 62**

S[2] S[5] **38, 97 OK**



SHELL SORT

Shell Sort Process k=1

30 62 53 42 17 97 91 38

Step 1: Buat sub list k =1

S[0]	S[1]	S[2]	S[3]	S[4]	S[5]	S[6]	S[7]
30	17	38	42	53	97	91	62
[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]

Step 2 - 3: Urutkan sub list & gabungkan

Sorting akan seperti insertion sort

17	30	38	42	53	62	91	97
[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]

DONE

Pemilihan Sequence Number

- Disarankan jarak mula-mula dari data yang akan dibandingkan adalah: **`N / 2`**.
- Pada proses berikutnya, digunakan jarak **`(N / 2) / 2`** atau **`N / 4`**.
- Pada proses berikutnya, digunakan jarak **`(N / 4) / 2`** atau **`N / 8`**.
- Demikian seterusnya sampai jarak yang digunakan adalah 1.

Urutan prosesnya...

- Untuk jarak N/2 :

  - Data pertama (i=0) dibandingkan dengan data dengan jarak N / 2. Apabila data pertama lebih besar dari data ke N / 2 tersebut maka kedua data tersebut ditukar.

  - Kemudian data kedua (i=1) dibandingkan dengan jarak yang sama yaitu N / 2 = elemen ke-(i+N/2)

  - Demikian seterusnya sampai seluruh data dibandingkan sehingga semua data ke-i selalu lebih kecil daripada data ke-(i + N / 2).
- Ulangi langkah-langkah di atas untuk jarak = N / 4 → lakukan pembandingan dan pengurutan sehingga semua data ke-i lebih kecil daripada data ke-(i + N / 4).
- Ulangi langkah-langkah di atas untuk jarak = N / 8 → lakukan pembandingan dan pengurutan sehingga semua data ke-i lebih kecil daripada data ke-(i + N / 8).
- Demikian seterusnya sampai jarak yang digunakan adalah 1 atau data sudah terurut (`did_swap = false`)

Algoritma Metode Shell Sort

1. **Jarak ← N**
2. Selama **Jarak > 1** kerjakan baris 3 sampai dengan 12
3. **Jarak ← Jarak / 2.**
4. **did_swap ← true**
5. Kerjakan baris 6 sampai dengan 12 selama **did_swap = true**
6. **did_swap ← false**
7. **i ← 0**
8. Selama **i < (N – Jarak)** kerjakan baris 9 sampai dengan 12
9. Jika **Data[i] > Data[i + Jarak]** kerjakan baris 10 dan 11
10. **tukar(Data[i], Data[i + Jarak])**
11. **did_swap ← true**
12. **i ← i + 1**

Analisis Metode Shell Sort

- Running time dari metode Shell Sort bergantung pada pemilihan sequence number-nya.
- Disarankan untuk memilih sequence number dimulai dari N/2, kemudian membaginya lagi dengan 2, seterusnya hingga mencapai 1.
- Shell sort menggunakan 3 nested loop, untuk merepresentasikan sebuah pengembangan yang substansial terhadap metode insertion sort

Pembandingan Running time (millisecond) antara insertion and Shell

N	insertion	Shellsort
1000	122	11
2000	483	26
4000	1936	61
8000	7950	153
16000	32560	358

Ref: Mark Allan Wiess
(Florida International University)

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7. RADIX SORT

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RADIX SORT

- Unlike the sorting algorithms described previously radix sort uses buckets to sort items, each bucket holds items with a particular property called a key.
- Normally a bucket is a queue, each time radix sort is performed these buckets are emptied starting the smallest key bucket to the largest.
- When looking at items within a list to sort we do so by isolating a special key, e.g. in the example we are about to show we have a maximum of three keys for all items, that is the highest key we need to look at is hundreds.
- Because we are dealing with, in this example base 10 numbers we have at any one point 10 possible key values 0..9 each of which has their own bucket

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RADIX SORT

- Before we show you this first simple version of radix sort let us clarify what we mean by isolating keys.
- Given the number 102 if we look at the first key, the ones then we can see we have two of
- them, progressing to the next key - tens we can see that the number has zero of them, finally we can see that the number has a single hundred.
- The number used as an example has in total three keys:
  1. Ones
  2. Tens
  3. Hundreds

RADIX SORT

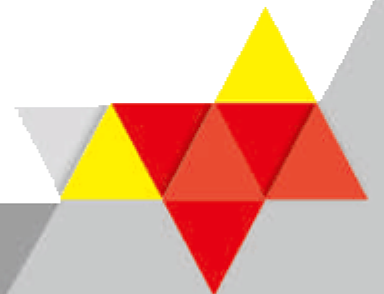
- For further clarification what if we wanted to determine how many thousands the number 102 has?
- Clearly there are none, but often looking at a number as final like we often do it is not so obvious so when asked the question how many thousands does 102 have you should simply pad the number with a zero in that location, e.g. 0102 here it is more obvious that the key value at the thousands location is zero.
- The last thing to identify before we actually show you a simple implementation of radix sort that works on only positive integers, and requires you to specify the maximum key size in the list is that we need a way to isolate a special key at any one time.
- The solution is actually very simple, but its not often you want to isolate a key in a number so we will spell it out clearly here.

RADIX SORT

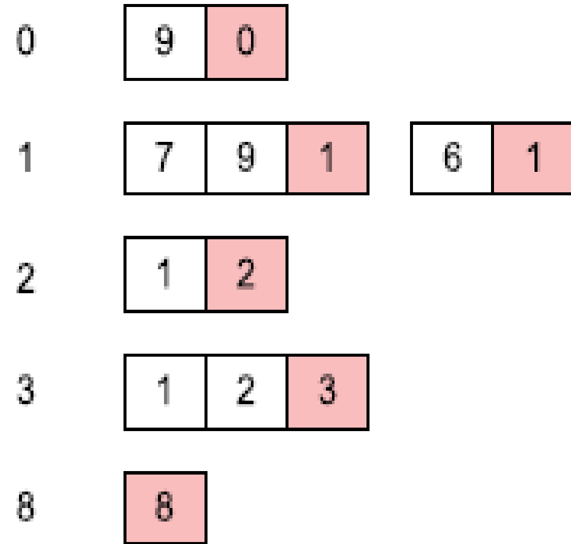
- A key can be accessed from any integer with the following expression:
  key ← (number / keyToAccess) % 10.
- As a simple example lets say that we want to access the tens key of the number 1290, the tens column is key 10 and so after substitution yields key ← (1290 = 10) % 10 = 9.
- The next key to look at for a number can be attained by multiplying the last key by ten working left to right in a sequential manner.
- The value of key is used in the following algorithm to work out the index of an array of queues to enqueue the item into.

RADIX SORT

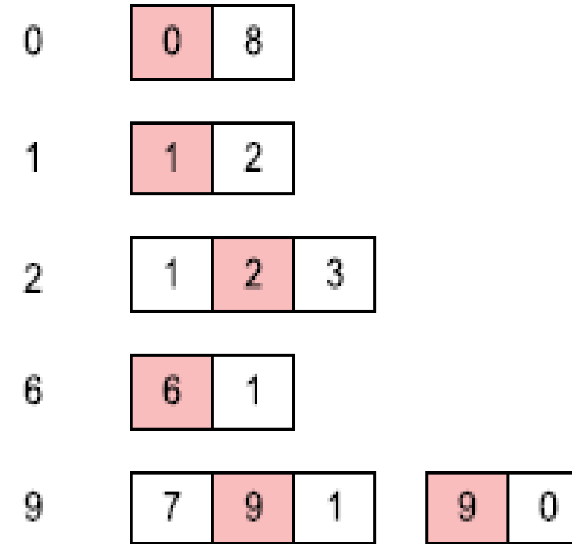
```
1) algorithm Radix(list, maxKeySize)
2)     Pre: list ≠ ∅
3)          maxKeySize ≥ 0 and represents the largest key size in the list
4)     Post: list has been sorted
5)     queues ← Queue[10]
6)     indexOfKey ← 1
7)     fori ← 0 to maxKeySize − 1
8)        foreach item in list
9)           queues[GetQueueIndex(item, indexOfKey)].Enqueue(item)
10)       end foreach
11)       list ← CollapseQueues(queues)
12)       ClearQueues(queues)
13)       indexOfKey ← indexOfKey ∗ 10
14)    end for
15)    return list
16) end Radix
```



RADIX SORT



a)



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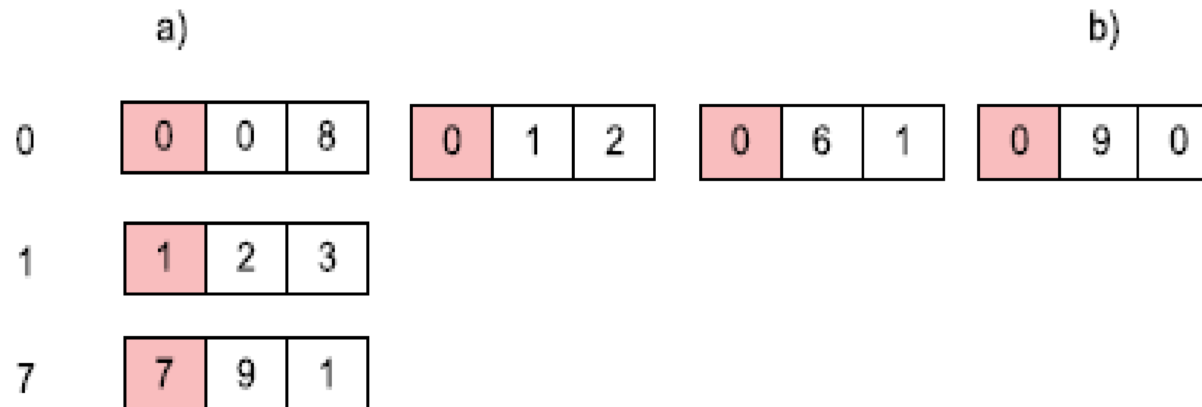

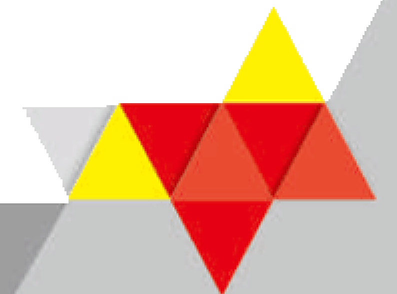

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