ĐẠI HỌC QUỐC GIA
ĐẠI HỌC BÁCH KHOA TP HỒ CHÍ MINH

BÀI TẬP LỚN MÔN KIẾN TRÚC MÁY TÍNH

LỚP L08 --- HK 201

ĐỀ 6

SẮP XẾP CHUỖI BẰNG GIẢI THUẬT MERGE SORT

Sinh viên thực hiện	Mã số sinh viên
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Thành phố Hồ Chí Minh – 2020

1. Code:

Hàm main trong chương trình:

```
233 ###############################################################################
234 main:
235 ###############################################################################
236         # Read the array
237         jal readArray
238         beq $v0, $zero, end                             # If read nothing, exit
239         # Print initial array
240         addu $a0, $v0, $zero                            # a0 = &array[0]
241         addu $a1, $v1, $zero                            # a1 = &array[last]
242         la $a2, noti1                                   # print with noti1
243         addiu $a3, $zero, '\n'                          # print '\n' at the end
244         jal printArray
245         # Sort array using mergeSort
246                                                         # Unchange a0 = first, a1 = last element of array
247         jal mergeSort
248         # Print sorted array
249                                                         # Unchange a0 = first, a1 = last element of array
250         la $a2, noti2                                   # Print with noti2
251                                                         # Unchange a3 = '\n'
252         jal printArray
253         # Unallocate memory for the array
254                                                         # Unchange a0 = first, a1 = last element of array
255         jal deleteArray
256 end:    addiu $v0, $zero, 10                            # Exit the program
257         syscall
258
```

2. Test case:

- Test case 1:

Clear

```
Initial array: -4 56 8 0 19 -31 145 7034 6 14 2020 -5 -46 10 827 -704 -1209 56091 1 -76
Divide: -4 56 8 0 19 -31 145 7034 6 14|2020 -5 -46 10 827 -704 -1209 56091 1 -76
Divide: -4 56 8 0 19|-31 145 7034 6 14
Divide: -4 56 8|0 19
Divide: -4 56|8
Divide: -4|56
Merge: -4&56
-----> -4 56
Merge: -4 56&8
-----> -4 8 56
Divide: 0|19
Merge: 0&19
-----> 0 19
Merge: -4 8 56&0 19
-----> -4 0 8 19 56
Divide: -31 145 7034|6 14
Divide: -31 145|7034
Divide: -31|145
Merge: -31&145
-----> -31 145
Merge: -31 145&7034
-----> -31 145 7034
Divide: 6|14
Merge: 6&14
-----> 6 14
Merge: -31 145 7034&6 14
-----> -31 6 14 145 7034
Merge: -4 0 8 19 56&-31 6 14 145 7034
-----> -31 -4 0 6 8 14 19 56 145 7034
```

Clear

```
Divide: 2020 -5 -46 10 827|-704 -1209 56091 1 -76
Divide: 2020 -5 -46|10 827
Divide: 2020 -5|-46
Divide: 2020|-5
Merge: 2020&-5
-----> -5 2020
Merge: -5 2020&-46
-----> -46 -5 2020
Divide: 10|827
Merge: 10&827
-----> 10 827
Merge: -46 -5 2020&10 827
-----> -46 -5 10 827 2020
Divide: -704 -1209 56091|1 -76
Divide: -704 -1209|56091
Divide: -704|-1209
Merge: -704&-1209
-----> -1209 -704
Merge: -1209 -704&56091
-----> -1209 -704 56091
Divide: 1|-76
Merge: 1&-76
-----> -76 1
Merge: -1209 -704 56091&-76 1
-----> -1209 -704 -76 1 56091
Merge: -46 -5 10 827 2020&-1209 -704 -76 1 56091
-----> -1209 -704 -76 -46 -5 1 10 827 2020 56091
Merge: -31 -4 0 6 8 14 19 56 145 7034&-1209 -704 -76 -46 -5 1 10 827 2020 56091
-----> -1209 -704 -76 -46 -31 -5 -4 0 1 6 8 10 14 19 56 145 827 2020 7034 56091
Sorted array: -1209 -704 -76 -46 -31 -5 -4 0 1 6 8 10 14 19 56 145 827 2020 7034 56091

-- program is finished running --
```

- Test case 2:

Clear

```
Initial array: -123456 12345 23 0 -234 435 564 1 -276 -457 6722 233 45 3456 12 -233 -146 -5 6 2
Divide: -123456 12345 23 0 -234 435 564 1 -276 -457|6722 233 45 3456 12 -233 -146 -5 6 2
Divide: -123456 12345 23 0 -234|435 564 1 -276 -457
Divide: -123456 12345 23|0 -234
Divide: -123456 12345|23
Divide: -123456|12345
Merge: -123456&12345
-----> -123456 12345
Merge: -123456 12345&23
-----> -123456 23 12345
Divide: 0|-234
Merge: 0&-234
-----> -234 0
Merge: -123456 23 12345&-234 0
-----> -123456 -234 0 23 12345
Divide: 435 564 1|-276 -457
Divide: 435 564|1
Divide: 435|564
Merge: 435&564
-----> 435 564
Merge: 435 564&1
-----> 1 435 564
Divide: -276|-457
Merge: -276&-457
-----> -457 -276
Merge: 1 435 564&-457 -276
-----> -457 -276 1 435 564
Merge: -123456 -234 0 23 12345&-457 -276 1 435 564
-----> -123456 -457 -276 -234 0 1 23 435 564 12345
```

Clear

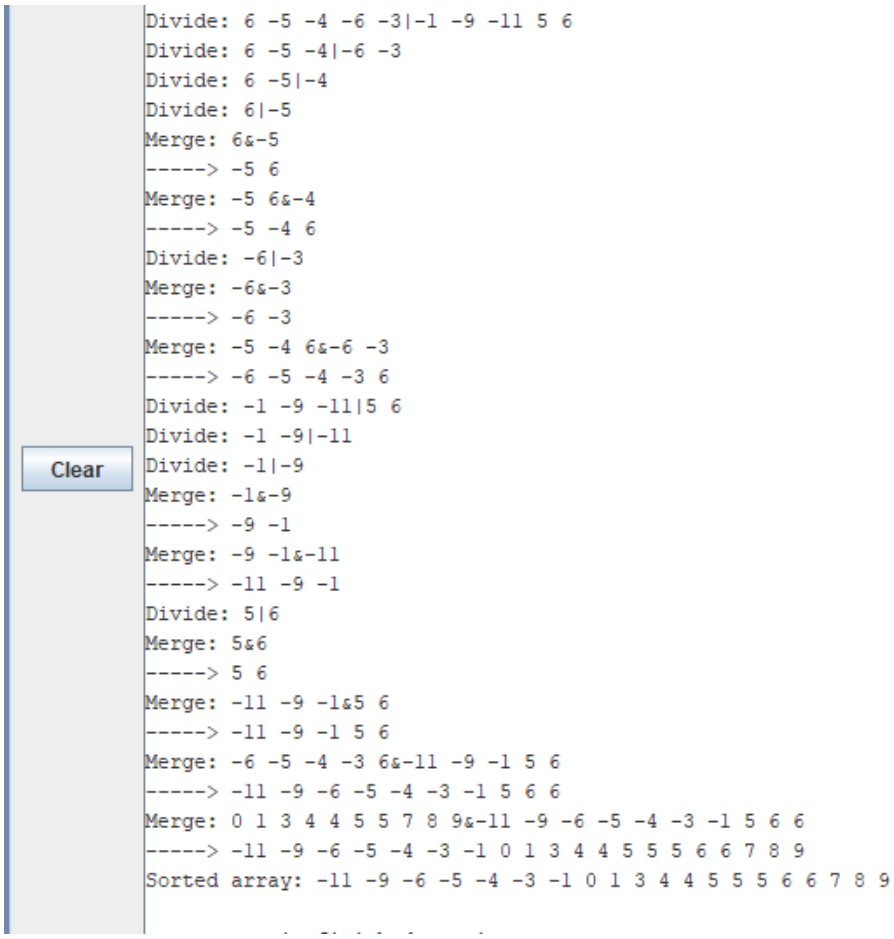
```
Divide: 6722 233 45 3456 12|-233 -146 -5 6 2
Divide: 6722 233 45|3456 12
Divide: 6722 233|45
Divide: 6722|233
Merge: 6722&233
-----> 233 6722
Merge: 233 6722&45
-----> 45 233 6722
Divide: 3456|12
Merge: 3456&12
-----> 12 3456
Merge: 45 233 6722&12 3456
-----> 12 45 233 3456 6722
Divide: -233 -146 -5|6 2
Divide: -233 -146|-5
Divide: -233|-146
Merge: -233&-146
-----> -233 -146
Merge: -233 -146&-5
-----> -233 -146 -5
Divide: 6|2
Merge: 6&2
-----> 2 6
Merge: -233 -146 -5&2 6
-----> -233 -146 -5 2 6
Merge: 12 45 233 3456 6722&-233 -146 -5 2 6
-----> -233 -146 -5 2 6 12 45 233 3456 6722
Merge: -123456 -457 -276 -234 0 1 23 435 564 12345&-233 -146 -5 2 6 12 45 233 3456 6722
-----> -123456 -457 -276 -234 -233 -146 -5 0 1 2 6 12 23 45 233 435 564 3456 6722 12345
Sorted array: -123456 -457 -276 -234 -233 -146 -5 0 1 2 6 12 23 45 233 435 564 3456 6722 12345

-- program is finished running --
```

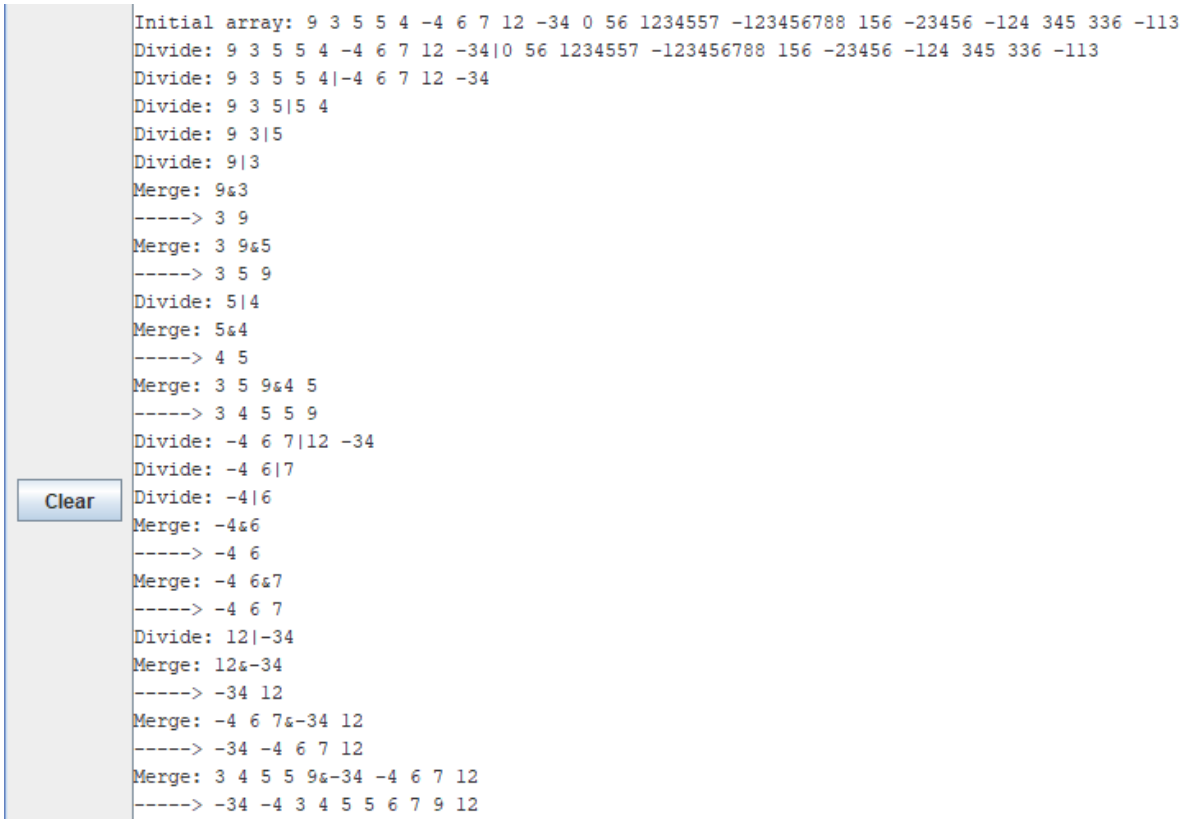
- Test case 3:

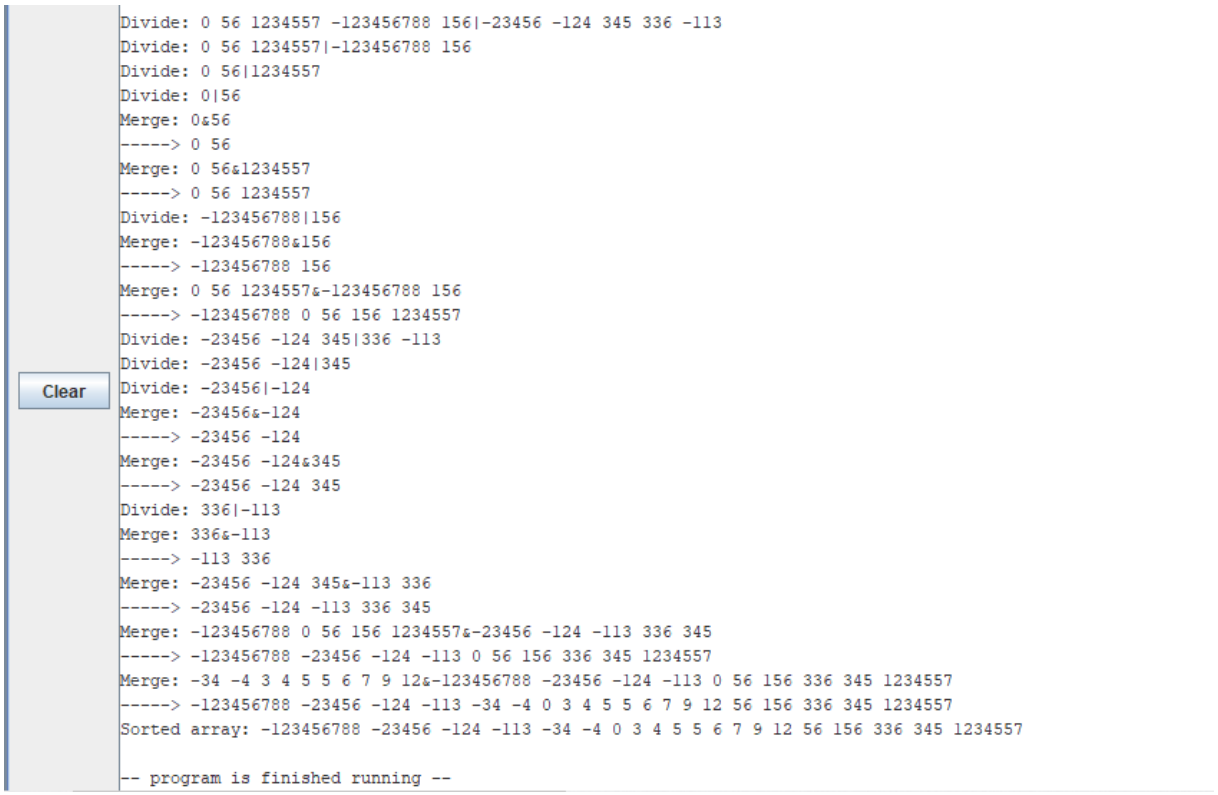
Clear

```
Initial array: 0 1 4 5 3 8 7 9 4 5 6 -5 -4 -6 -3 -1 -9 -11 5 6
Divide: 0 1 4 5 3 8 7 9 4 5|6 -5 -4 -6 -3 -1 -9 -11 5 6
Divide: 0 1 4 5 3|8 7 9 4 5
Divide: 0 1 4|5 3
Divide: 0 1|4
Divide: 0|1
Merge: 0&1
-----> 0 1
Merge: 0 1&4
-----> 0 1 4
Divide: 5|3
Merge: 5&3
-----> 3 5
Merge: 0 1 4&3 5
-----> 0 1 3 4 5
Divide: 8 7 9|4 5
Divide: 8 7|9
Divide: 8|7
Merge: 8&7
-----> 7 8
Merge: 7 8&9
-----> 7 8 9
Divide: 4|5
Merge: 4&5
-----> 4 5
Merge: 7 8 9&4 5
-----> 4 5 7 8 9
Merge: 0 1 3 4 5&4 5 7 8 9
-----> 0 1 3 4 4 5 5 7 8 9
```

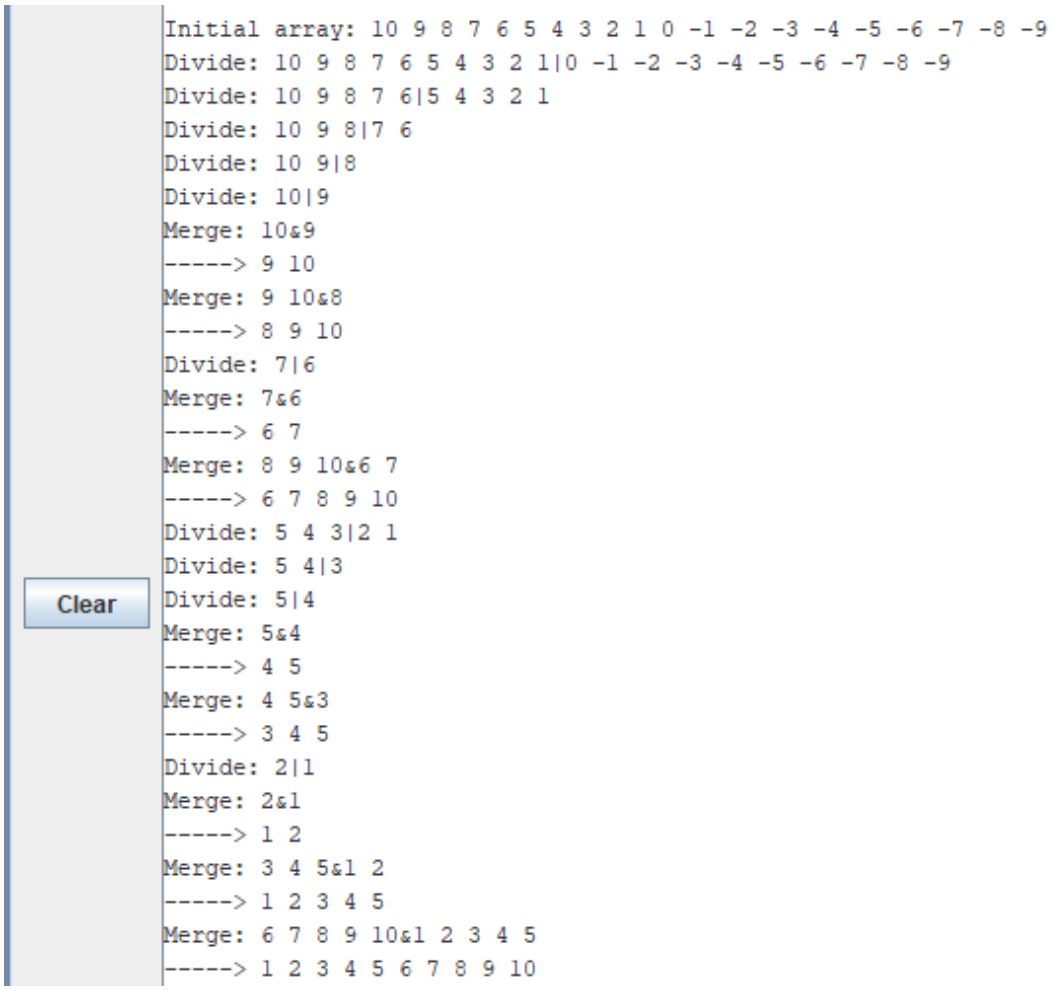

Clear
Divide: 6 -5 -4 -6 -3|-1 -9 -11 5 6
Divide: 6 -5 -4|-6 -3
Divide: 6 -5|-4
Divide: 6|-5
Merge: 6&-5
-----> -5 6
Merge: -5 6&-4
-----> -5 -4 6
Divide: -6|-3
Merge: -6&-3
-----> -6 -3
Merge: -5 -4 6&-6 -3
-----> -6 -5 -4 -3 6
Divide: -1 -9 -11|5 6
Divide: -1 -9|-11
Divide: -1|-9
Merge: -1&-9
-----> -9 -1
Merge: -9 -1&-11
-----> -11 -9 -1
Divide: 5|6
Merge: 5&6
-----> 5 6
Merge: -11 -9 -1&5 6
-----> -11 -9 -1 5 6
Merge: -6 -5 -4 -3 6&-11 -9 -1 5 6
-----> -11 -9 -6 -5 -4 -3 -1 5 6 6
Merge: 0 1 3 4 4 5 5 7 8 9&-11 -9 -6 -5 -4 -3 -1 5 6 6
-----> -11 -9 -6 -5 -4 -3 -1 0 1 3 4 4 5 5 5 6 6 7 8 9
Sorted array: -11 -9 -6 -5 -4 -3 -1 0 1 3 4 4 5 5 5 6 6 7 8 9

- Test case 4:


Clear
Initial array: 9 3 5 5 4 -4 6 7 12 -34 0 56 1234557 -123456788 156 -23456 -124 345 336 -113
Divide: 9 3 5 5 4 -4 6 7 12 -34|0 56 1234557 -123456788 156 -23456 -124 345 336 -113
Divide: 9 3 5 5 4|-4 6 7 12 -34
Divide: 9 3 5|5 4
Divide: 9 3|5
Divide: 9|3
Merge: 9&3
-----> 3 9
Merge: 3 9&5
-----> 3 5 9
Divide: 5|4
Merge: 5&4
-----> 4 5
Merge: 3 5 9&4 5
-----> 3 4 5 5 9
Divide: -4 6 7|12 -34
Divide: -4 6|7
Divide: -4|6
Merge: -4&6
-----> -4 6
Merge: -4 6&7
-----> -4 6 7
Divide: 12|-34
Merge: 12&-34
-----> -34 12
Merge: -4 6 7&-34 12
-----> -34 -4 6 7 12
Merge: 3 4 5 5 9&-34 -4 6 7 12
-----> -34 -4 3 4 5 5 6 7 9 12


Clear
Divide: 0 56 1234557 -123456788 156|-23456 -124 345 336 -113
Divide: 0 56 1234557|-123456788 156
Divide: 0 56|1234557
Divide: 0|56
Merge: 0&56
-----> 0 56
Merge: 0 56&1234557
-----> 0 56 1234557
Divide: -123456788|156
Merge: -123456788&156
-----> -123456788 156
Merge: 0 56 1234557&-123456788 156
-----> -123456788 0 56 156 1234557
Divide: -23456 -124 345|336 -113
Divide: -23456 -124|345
Divide: -23456|-124
Merge: -23456&-124
-----> -23456 -124
Merge: -23456 -124&345
-----> -23456 -124 345
Divide: 336|-113
Merge: 336&-113
-----> -113 336
Merge: -23456 -124 345&-113 336
-----> -23456 -124 -113 336 345
Merge: -123456788 0 56 156 1234557&-23456 -124 -113 336 345
-----> -123456788 -23456 -124 -113 0 56 156 336 345 1234557
Merge: -34 -4 3 4 5 5 6 7 9 12&-123456788 -23456 -124 -113 0 56 156 336 345 1234557
-----> -123456788 -23456 -124 -113 -34 -4 0 3 4 5 5 6 7 9 12 56 156 336 345 1234557
Sorted array: -123456788 -23456 -124 -113 -34 -4 0 3 4 5 5 6 7 9 12 56 156 336 345 1234557
-- program is finished running --

- Test case 5:


Clear
Initial array: 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9
Divide: 10 9 8 7 6 5 4 3 2 1|0 -1 -2 -3 -4 -5 -6 -7 -8 -9
Divide: 10 9 8 7 6|5 4 3 2 1
Divide: 10 9 8|7 6
Divide: 10 9|8
Divide: 10|9
Merge: 10&9
-----> 9 10
Merge: 9 10&8
-----> 8 9 10
Divide: 7|6
Merge: 7&6
-----> 6 7
Merge: 8 9 10&6 7
-----> 6 7 8 9 10
Divide: 5 4 3|2 1
Divide: 5 4|3
Divide: 5|4
Merge: 5&4
-----> 4 5
Merge: 4 5&3
-----> 3 4 5
Divide: 2|1
Merge: 2&1
-----> 1 2
Merge: 3 4 5&1 2
-----> 1 2 3 4 5
Merge: 6 7 8 9 10&1 2 3 4 5
-----> 1 2 3 4 5 6 7 8 9 10

Clear

```
Divide: 0 -1 -2 -3 -4|-5 -6 -7 -8 -9
Divide: 0 -1 -2|-3 -4
Divide: 0 -1|-2
Divide: 0|-1
Merge: 0&-1
-----> -1 0
Merge: -1 0&-2
-----> -2 -1 0
Divide: -3|-4
Merge: -3&-4
-----> -4 -3
Merge: -2 -1 0&-4 -3
-----> -4 -3 -2 -1 0
Divide: -5 -6 -7|-8 -9
Divide: -5 -6|-7
Divide: -5|-6
Merge: -5&-6
-----> -6 -5
Merge: -6 -5&-7
-----> -7 -6 -5
Divide: -8|-9
Merge: -8&-9
-----> -9 -8
Merge: -7 -6 -5&-9 -8
-----> -9 -8 -7 -6 -5
Merge: -4 -3 -2 -1 0&-9 -8 -7 -6 -5
-----> -9 -8 -7 -6 -5 -4 -3 -2 -1 0
Merge: 1 2 3 4 5 6 7 8 9 10&-9 -8 -7 -6 -5 -4 -3 -2 -1 0
-----> -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
Sorted array: -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

-- program is finished running --
```

- Test case 6:

Clear

```
Initial array: 1 3 5 7 9 2 4 6 8 10 11 13 15 17 19 12 14 16 18 20
Divide: 1 3 5 7 9 2 4 6 8 10|11 13 15 17 19 12 14 16 18 20
Divide: 1 3 5 7 9|2 4 6 8 10
Divide: 1 3 5|7 9
Divide: 1 3|5
Divide: 1|3
Merge: 1&3
-----> 1 3
Merge: 1 3&5
-----> 1 3 5
Divide: 7|9
Merge: 7&9
-----> 7 9
Merge: 1 3 5&7 9
-----> 1 3 5 7 9
Divide: 2 4 6|8 10
Divide: 2 4|6
Divide: 2|4
Merge: 2&4
-----> 2 4
Merge: 2 4&6
-----> 2 4 6
Divide: 8|10
Merge: 8&10
-----> 8 10
Merge: 2 4 6&8 10
-----> 2 4 6 8 10
Merge: 1 3 5 7 9&2 4 6 8 10
-----> 1 2 3 4 5 6 7 8 9 10
```

Clear

```
Divide: 11 13 15 17 19|12 14 16 18 20
Divide: 11 13 15|17 19
Divide: 11 13|15
Divide: 11|13
Merge: 11&13
-----> 11 13
Merge: 11 13&15
-----> 11 13 15
Divide: 17|19
Merge: 17&19
-----> 17 19
Merge: 11 13 15&17 19
-----> 11 13 15 17 19
Divide: 12 14 16|18 20
Divide: 12 14|16
Divide: 12|14
Merge: 12&14
-----> 12 14
Merge: 12 14&16
-----> 12 14 16
Divide: 18|20
Merge: 18&20
-----> 18 20
Merge: 12 14 16&18 20
-----> 12 14 16 18 20
Merge: 11 13 15 17 19&12 14 16 18 20
-----> 11 12 13 14 15 16 17 18 19 20
Merge: 1 2 3 4 5 6 7 8 9 10&11 12 13 14 15 16 17 18 19 20
-----> 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Sorted array: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

-- program is finished running --
```

- Test case 7:

Clear

```
Initial array: 2 2 2 2 1 1 1 1 3 3 3 -1 -1 0 0 0 5 5 6 6
Divide: 2 2 2 2 1 1 1 1 3 3|3 -1 -1 0 0 0 5 5 6 6
Divide: 2 2 2 2 1|1 1 1 3 3
Divide: 2 2 2|2 1
Divide: 2 2|2
Divide: 2|2
Merge: 2&2
-----> 2 2
Merge: 2 2&2
-----> 2 2 2
Divide: 2|1
Merge: 2&1
-----> 1 2
Merge: 2 2 2&1 2
-----> 1 2 2 2 2
Divide: 1 1 1|3 3
Divide: 1 1|1
Divide: 1|1
Merge: 1&1
-----> 1 1
Merge: 1 1&1
-----> 1 1 1
Divide: 3|3
Merge: 3&3
-----> 3 3
Merge: 1 1 1&3 3
-----> 1 1 1 3 3
Merge: 1 2 2 2 2&1 1 1 3 3
-----> 1 1 1 1 2 2 2 2 3 3
```

Clear

```
Divide: 3 -1 -1 0 0|0 5 5 6 6
Divide: 3 -1 -1|0 0
Divide: 3 -1|-1
Divide: 3|-1
Merge: 3&-1
-----> -1 3
Merge: -1 3&-1
-----> -1 -1 3
Divide: 0|0
Merge: 0&0
-----> 0 0
Merge: -1 -1 3&0 0
-----> -1 -1 0 0 3
Divide: 0 5 5|6 6
Divide: 0 5|5
Divide: 0|5
Merge: 0&5
-----> 0 5
Merge: 0 5&5
-----> 0 5 5
Divide: 6|6
Merge: 6&6
-----> 6 6
Merge: 0 5 5&6 6
-----> 0 5 5 6 6
Merge: -1 -1 0 0 3&0 5 5 6 6
-----> -1 -1 0 0 0 3 5 5 6 6
Merge: 1 1 1 1 2 2 2 2 3 3&-1 -1 0 0 0 3 5 5 6 6
-----> -1 -1 0 0 0 1 1 1 1 2 2 2 2 3 3 3 5 5 6 6
Sorted array: -1 -1 0 0 0 1 1 1 1 2 2 2 2 3 3 3 5 5 6 6

-- program is finished running --
```

- Test case 8:

Clear

```
Initial array: -3 -5 -7 1 2 4 -5 -8 2 2 3 -9 -5 -7 12 20 -8 35 13 24
Divide: -3 -5 -7 1 2 4 -5 -8 2 2|3 -9 -5 -7 12 20 -8 35 13 24
Divide: -3 -5 -7 1 2|4 -5 -8 2 2
Divide: -3 -5 -7|1 2
Divide: -3 -5|-7
Divide: -3|-5
Merge: -3&-5
-----> -5 -3
Merge: -5 -3&-7
-----> -7 -5 -3
Divide: 1|2
Merge: 1&2
-----> 1 2
Merge: -7 -5 -3&1 2
-----> -7 -5 -3 1 2
Divide: 4 -5 -8|2 2
Divide: 4 -5|-8
Divide: 4|-5
Merge: 4&-5
-----> -5 4
Merge: -5 4&-8
-----> -8 -5 4
Divide: 2|2
Merge: 2&2
-----> 2 2
Merge: -8 -5 4&2 2
-----> -8 -5 2 2 4
Merge: -7 -5 -3 1 2&-8 -5 2 2 4
-----> -8 -7 -5 -5 -3 1 2 2 2 4
```

Clear

```
Divide: 3 -9 -5 -7 12|20 -8 35 13 24
Divide: 3 -9 -5|-7 12
Divide: 3 -9|-5
Divide: 3|-9
Merge: 3&-9
-----> -9 3
Merge: -9 3&-5
-----> -9 -5 3
Divide: -7|12
Merge: -7&12
-----> -7 12
Merge: -9 -5 3&-7 12
-----> -9 -7 -5 3 12
Divide: 20 -8 35|13 24
Divide: 20 -8|35
Divide: 20|-8
Merge: 20&-8
-----> -8 20
Merge: -8 20&35
-----> -8 20 35
Divide: 13|24
Merge: 13&24
-----> 13 24
Merge: -8 20 35&13 24
-----> -8 13 20 24 35
Merge: -9 -7 -5 3 12&-8 13 20 24 35
-----> -9 -8 -7 -5 3 12 13 20 24 35
Merge: -8 -7 -5 -5 -3 1 2 2 2 4&-9 -8 -7 -5 3 12 13 20 24 35
-----> -9 -8 -8 -7 -7 -5 -5 -5 -3 1 2 2 2 3 4 12 13 20 24 35
Sorted array: -9 -8 -8 -7 -7 -5 -5 -5 -3 1 2 2 2 3 4 12 13 20 24 35

-- program is finished running --
```

- Test case 9:

Clear

```
Initial array: 0 7 1 2 2 0 0 1 3 0 1 2 2 0 0 1 2 3 4 5
Divide: 0 7 1 2 2 0 0 1 3 0|1 2 2 0 0 1 2 3 4 5
Divide: 0 7 1 2 2|0 0 1 3 0
Divide: 0 7 1|2 2
Divide: 0 7|1
Divide: 0|7
Merge: 0&7
-----> 0 7
Merge: 0 7&1
-----> 0 1 7
Divide: 2|2
Merge: 2&2
-----> 2 2
Merge: 0 1 7&2 2
-----> 0 1 2 2 7
Divide: 0 0 1|3 0
Divide: 0 0|1
Divide: 0|0
Merge: 0&0
-----> 0 0
Merge: 0 0&1
-----> 0 0 1
Divide: 3|0
Merge: 3&0
-----> 0 3
Merge: 0 0 1&0 3
-----> 0 0 0 1 3
Merge: 0 1 2 2 7&0 0 0 1 3
-----> 0 0 0 0 1 1 2 2 3 7
```

Clear

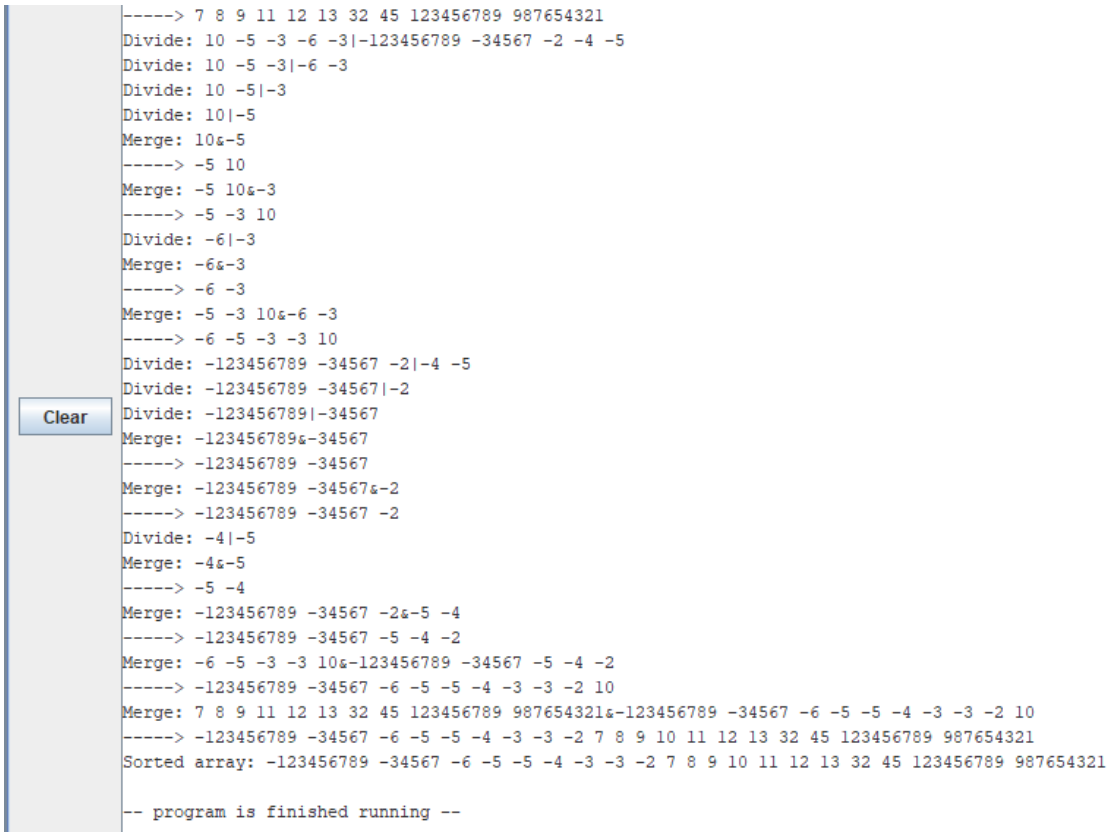
```
Divide: 1 2 2 0 0|1 2 3 4 5
Divide: 1 2 2|0 0
Divide: 1 2|2
Divide: 1|2
Merge: 1&2
-----> 1 2
Merge: 1 2&2
-----> 1 2 2
Divide: 0|0
Merge: 0&0
-----> 0 0
Merge: 1 2 2&0 0
-----> 0 0 1 2 2
Divide: 1 2 3|4 5
Divide: 1 2|3
Divide: 1|2
Merge: 1&2
-----> 1 2
Merge: 1 2&3
-----> 1 2 3
Divide: 4|5
Merge: 4&5
-----> 4 5
Merge: 1 2 3&4 5
-----> 1 2 3 4 5
Merge: 0 0 1 2 2&1 2 3 4 5
-----> 0 0 1 1 2 2 2 3 4 5
Merge: 0 0 0 0 1 1 2 2 3 7&0 0 1 1 2 2 2 3 4 5
-----> 0 0 0 0 0 0 0 1 1 1 1 2 2 2 2 2 3 3 4 5 7
Sorted array: 0 0 0 0 0 0 0 1 1 1 1 2 2 2 2 2 3 3 4 5 7

-- program is finished running --
```

- Test case 10:

Clear

```
Initial array: 123456789 9 8 7 987654321 12 13 45 32 11 10 -5 -3 -6 -3 -123456789 -34567 -2 -4 -5
Divide: 123456789 9 8 7 987654321 12 13 45 32 11|10 -5 -3 -6 -3 -123456789 -34567 -2 -4 -5
Divide: 123456789 9 8 7 987654321|12 13 45 32 11
Divide: 123456789 9 8|7 987654321
Divide: 123456789 9|8
Divide: 123456789|9
Merge: 123456789&9
-----> 9 123456789
Merge: 9 123456789&8
-----> 8 9 123456789
Divide: 7|987654321
Merge: 7&987654321
-----> 7 987654321
Merge: 8 9 123456789&7 987654321
-----> 7 8 9 123456789 987654321
Divide: 12 13 45|32 11
Divide: 12 13|45
Divide: 12|13
Merge: 12&13
-----> 12 13
Merge: 12 13&45
-----> 12 13 45
Divide: 32|11
Merge: 32&11
-----> 11 32
Merge: 12 13 45&11 32
-----> 11 12 13 32 45
Merge: 7 8 9 123456789 987654321&11 12 13 32 45
-----> 7 8 9 11 12 13 32 45 123456789 987654321
```



3. Thống kê số lệnh, loại lệnh:

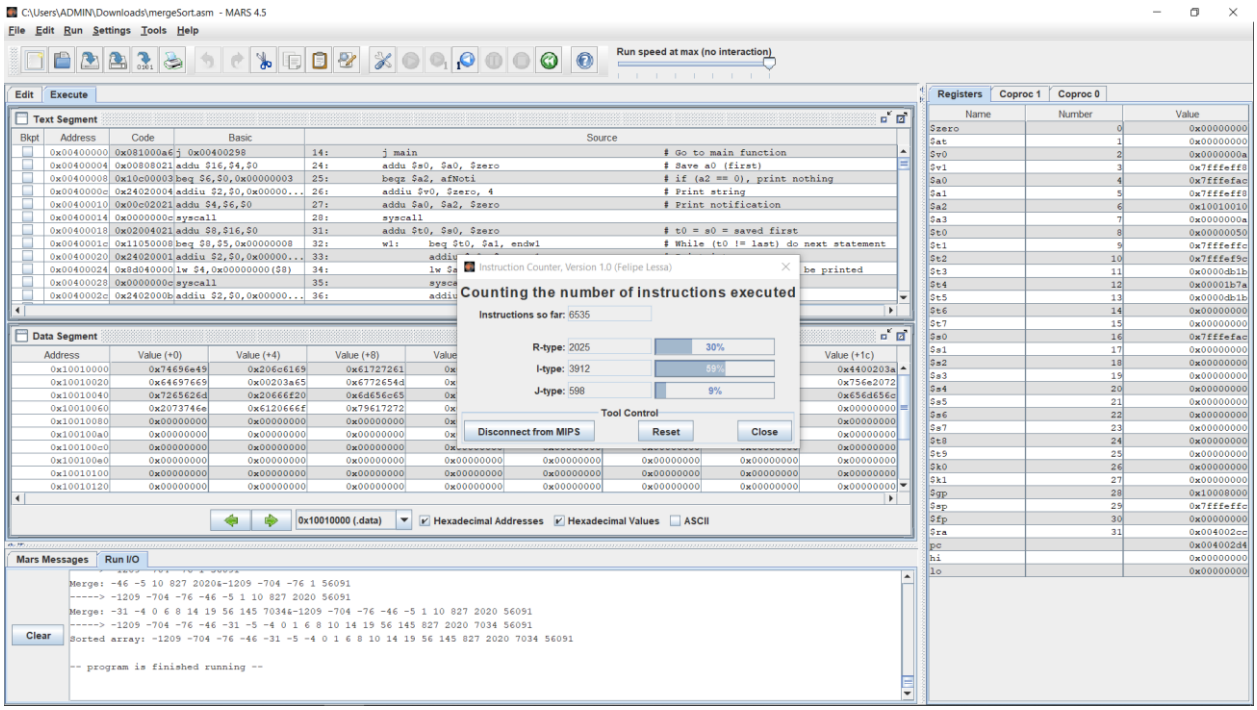
Sử dụng test case sau:

Initial array: -4 56 8 0 19 -31 145 7034 6 14 2020 -5 -46 10 827 -704 -1209 56091 1 -76

Sorted array: -1209 -704 -76 -46 -31 -5 -4 0 1 6 8 10 14 19 56 145 827 2020 7034 56091

- Tính số lệnh và phân loại theo định dạng R, I, J, sử dụng

$Tools \rightarrow Instruction\ Counter$:



Tổng số lệnh: 6535

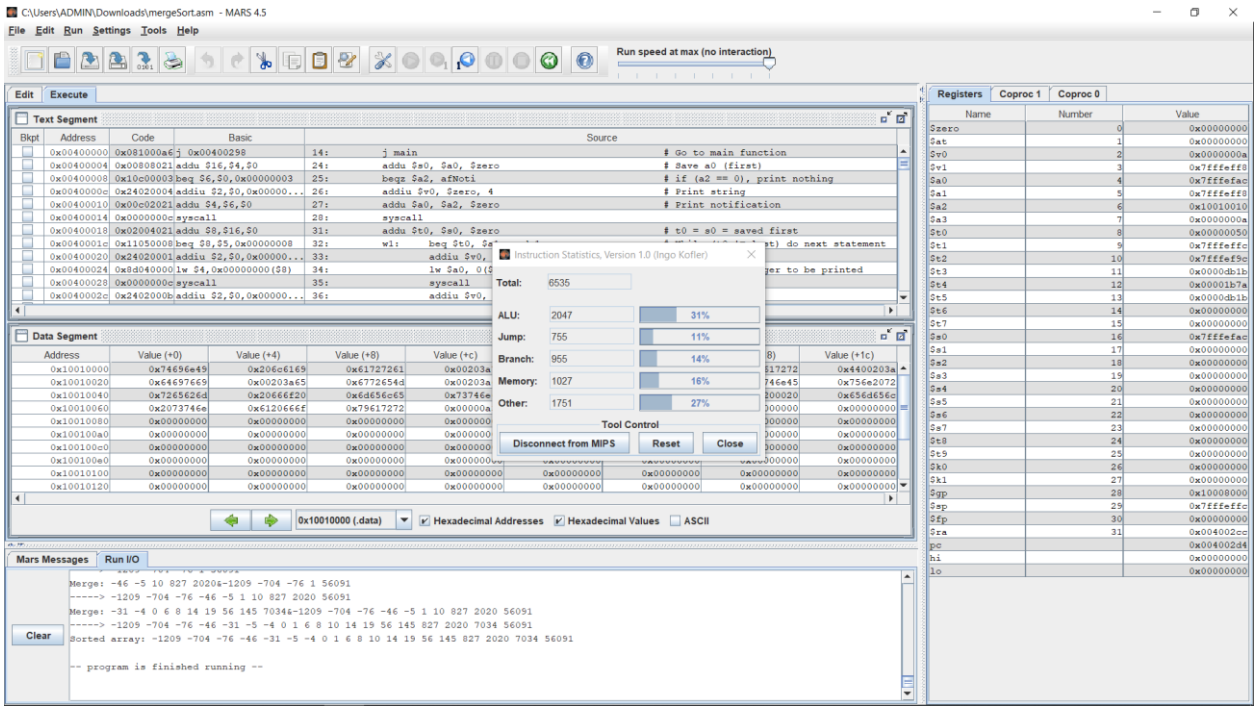
Số lệnh dạng R: 2025

Số lệnh dạng I: 3912

Số lệnh dạng J: 598

- Tính số lệnh và phân loại theo chức năng, sử dụng

Tools → Instruction Statistics:



Tổng số lệnh: 6535

Số lệnh ALU: 2047

Số lệnh Jump: 755

Số lệnh Branch: 955

Số lệnh Memory: 1027

Số lệnh khác: 1751

4. Tính thời gian chạy của chương trình:

Thời gian chạy chương trình được xác định thông qua thời gian thực thi của CPU (CPU time).

CPU time được tính theo công thức:

$$\begin{aligned}\text{CPU time} &= \text{CPU clock cycles x Clock cycle time} \\ &= \text{Instruction count x CPI x Clock cycle time} \\ &= \frac{\text{Instruction count x CPI}}{\text{Clock rate}}\end{aligned}$$

Trong đó:

CPU time : thời gian thực thi của CPU

CPU clock cycles : số chu kỳ của chương trình

Clock cycle time : thời gian một chu kỳ xung nhịp

Instruction count : số lệnh thực thi

CPI : số chu kỳ của mỗi lệnh

Clock rate : tần số xung nhịp

Dựa vào công thức trên với:

Instruction count = 6535

CPI = 1

Clock rate = 2GHz

Ta có:

$$\text{CPU time} = \frac{(6535 \text{ x } 1)}{(2 \text{ x } 10^9)} = 3267{,}5 \text{ x } 10^{-9}(\text{s}) = 3267{,}5(\text{ns})$$