GIẢI THUẬT MERGESORT
BẰNG HỢP NGỮ ASSEMBLY MIPS

GVHD: Trần Thanh Bình
SV thực hiện: Nguyễn Ngọc Thái An – 1910006
             Nhan Minh Châu – 1910060
             Nguyễn Kim Phương Trang – 1910620

Tp. Hồ Chí Minh, Tháng 12/2020

Mục lục

1   Mã giả giải thuật hiện thực trong MIPS

1. Tạo stack lưu giá trị
   - Địa chỉ trả về
   - Địa chỉ mảng
   - Lưu $right$
   - Lưu mid
   - Lưu $left$

2. $mid = (right + left)/2$

3. Cập nhật thanh ghi lưu giá trị right thành mid (để recursive cho $left, mid$)

4. Gọi đệ quy để $MSort$ nửa trái (Điều kiện dừng là $low >= hight$)

5. Cập nhật giá trị $mid = mid + 1$ (để recursive cho $mid + 1, right$)

6. Sau đó nhảy đến hàm $Merge$

7. Tạo stack lưu giá trị
   - Địa chỉ trả về
   - Địa chỉ mảng
   - Lưu $right$
   - Lưu mid
   - Lưu $left$

8. Trong lúc merge in ra các bước

9. Khi 2 nửa mảng đều còn chứa phần tử
   - Kiểm tra $a[i]$ và $a[j]$
   - Phần tử nào nhỏ hơn thì đẩy vào $array2$

10. Vét phần tử còn lại trong đoạn $left, mid$. Nếu hết thì nhảy qua $while3$ vét phần tử đoạn $mid + 1, right$

11. Duyệt chuyển toàn bộ phần tử $array2$ qua $array$

12. Kết thúc giải thuật

   Hàm MSort sẽ gọi đệ quy liên tục tới khi tách mảng ra có các phần tử riêng lẻ Sau đó hàm Done sẽ trả giá trị từ stack về cho left,mid,right để gọi hàm Merge từng các giá trị lại với nhau Nhiệm vụ của Stack y như nhiệm vụ của bộ nhớ stack lúc gọi đệ quy.

2   Testcases

Ứng với mỗi đầu vào là mảng có 20 phần tử, thực hiện in ra mảng sau mỗi bước MERGE 2 mảng con lại với các tham số $left, mid, right$. Tổng cộng có 19 lần MERGE 2 mảng con để kết thúc thuật toán sắp xếp Mergesort có 20 phần tử sắp xếp theo thứ tự không giảm.

Vì Mergesort là thuật toán ổn định, ứng với các đầu vào khác nhau, thuật toán đều tạo ra độ phức tạp trong các trường hợp Worst case, Average case và Best case là $O(n * logn)$, với n là số lượng phần tử trong mảng cần sắp xếp. Ta có thể nhận ra điều này qua bảng thống kê *Instructions Statistics* được trình bày ứng với mỗi testcase bên dưới.Tổng số lệnh *Total* sau khi thực thi xong chương trình đều khoảng 16000 ứng với các đầu vào khác nhau.

2.1 Testcase 1

Mảng đầu vào ngẫu nhiên với các số nguyên dương nằm trong đoạn[1, 20]

[Console output screenshot showing merge sort execution trace with "Mang ban dau", repeated SORT/MERGE lines with left/mid/right indices, ending with "Mang da sap xep: 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0" and "-- program is finished running --"]

Instruction Statistics, Version 1.0 (Ingo ...)

Total:	16504
ALU:	7864 — 48%
Jump:	1217 — 7%
Branch:	2350 — 14%
Memory:	828 — 5%
Other:	4245 — 26%

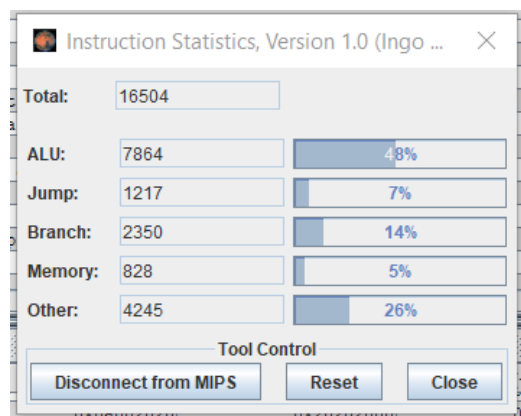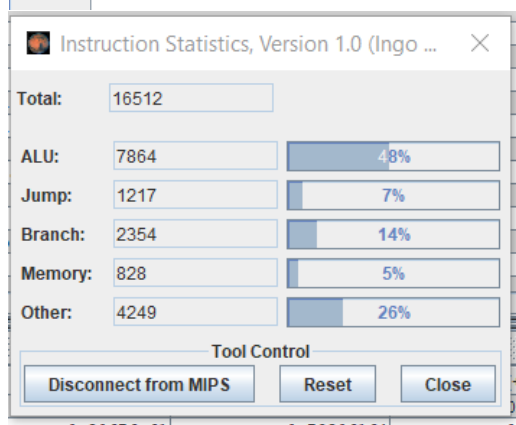Tool Control

Disconnect from MIPS | Reset | Close

2.2   Testcase 2

Mảng đầu vào ngẫu nhiên với các số nguyên nằm trong đoạn $[0, 19]$

```
Mang ban dau: 18.0   16.0   14.0   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 18.0   16.0   14.0   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 0        mid: 0        right: 1
MERGE: | 18.0 |    16.0 |   14.0   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 16.0   18.0   14.0   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 0        mid: 1        right: 2
MERGE: | 16.0   18.0 |   14.0 |   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 14.0   16.0   18.0   12.0   10.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 3        mid: 3        right: 4
MERGE: 14.0   16.0   18.0   | 12.0 |    10.0 |   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 14.0   16.0   18.0   10.0   12.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 0        mid: 2        right: 4
MERGE: | 14.0   16.0   18.0 |   10.0   12.0 |   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 10.0   12.0   14.0   16.0   18.0   8.0   6.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 5        mid: 5        right: 6
MERGE: 10.0   12.0   14.0   16.0   18.0   | 8.0 |    6.0 |   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 10.0   12.0   14.0   16.0   18.0   6.0   8.0   4.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 5        mid: 6        right: 7
MERGE: 10.0   12.0   14.0   16.0   18.0   | 6.0   8.0 |   4.0 |   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 10.0   12.0   14.0   16.0   18.0   4.0   6.0   8.0   2.0   0.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 8        mid: 8        right: 9
MERGE: 10.0   12.0   14.0   16.0   18.0   4.0   6.0   8.0   | 2.0 |   0.0 |   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 10.0   12.0   14.0   16.0   18.0   4.0   6.0   8.0   0.0   2.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 5        mid: 7        right: 9
MERGE: 10.0   12.0   14.0   16.0   18.0   | 4.0   6.0   8.0 |   0.0   2.0 |   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 10.0   12.0   14.0   16.0   18.0   0.0   2.0   4.0   6.0   8.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 0        mid: 4        right: 9
MERGE: | 10.0   12.0   14.0   16.0   18.0 |   0.0   2.0   4.0   6.0   8.0 |   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 10        mid: 10        right: 11
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   | 1.0 |    3.0 |   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 10        mid: 11        right: 12
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   | 1.0   3.0 |   5.0 |   7.0   9.0   11.0   13.0   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 13        mid: 13        right: 14
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   | 7.0 |    9.0 |   11.0   13.0   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 10        mid: 12        right: 14
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   | 1.0   3.0   5.0 |   7.0   9.0 |   11.0   13.0   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 15        mid: 15        right: 16
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   | 11.0 |    13.0 |   15.0   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 15        mid: 16        right: 17
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   | 11.0   13.0 |   15.0 |   17.0   19.0
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 18        mid: 18        right: 19
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   | 17.0 |    19.0 |
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 15        mid: 17        right: 19
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   | 11.0   13.0   15.0 |   17.0   19.0 |
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 10        mid: 14        right: 19
MERGE: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   | 1.0   3.0   5.0   7.0   9.0 |   11.0   13.0   15.0   17.0   19.0 |
SORT: 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0
 left: 0        mid: 9        right: 19
MERGE: | 0.0   2.0   4.0   6.0   8.0   10.0   12.0   14.0   16.0   18.0 |   1.0   3.0   5.0   7.0   9.0   11.0   13.0   15.0   17.0   19.0 |
Mang da sap xep: 0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0
-- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo ... ✕		
Total:	16512	
ALU:	7864	48%
Jump:	1217	7%
Branch:	2354	14%
Memory:	828	5%
Other:	4249	26%

Tool Control

Disconnect from MIPS   Reset   Close
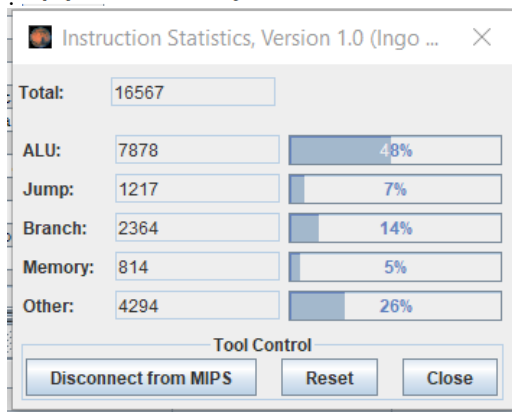
2.3 Testcase 3

Mảng đầu vào ngẫu nhiên có cả số nguyên âm, nguyên dương

```
Mang ban dau: 19.0   -18.0   17.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: 19.0   -18.0   17.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 0      mid: 0       right: 1
MERGE: | 19.0 |   -18.0 |   17.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   19.0   17.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 0      mid: 1       right: 2
MERGE: | -18.0   19.0 |   17.0 |   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   17.0   19.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 3      mid: 3       right: 4
MERGE: -18.0   17.0   19.0   | -16.0 |   15.0 |   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   17.0   19.0   -16.0   15.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 0      mid: 2       right: 4
MERGE: | -18.0   17.0   19.0 |   -16.0   15.0 |   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   15.0   17.0   19.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 5      mid: 5       right: 6
MERGE: -18.0   -16.0   15.0   17.0   19.0   | -14.0 |   16.0 |   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   15.0   17.0   19.0   -14.0   16.0   -13.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 5      mid: 6       right: 7
MERGE: -18.0   -16.0   15.0   17.0   19.0   | -14.0   16.0 |   -13.0 |   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   15.0   17.0   19.0   -14.0   -13.0   16.0   13.0   -12.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 8      mid: 8       right: 9
MERGE: -18.0   -16.0   15.0   17.0   19.0   -14.0   -13.0   16.0   | 13.0 |   -12.0 |   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   15.0   17.0   19.0   -14.0   -13.0   16.0   -12.0   13.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 5      mid: 7       right: 9
MERGE: -18.0   -16.0   15.0   17.0   19.0   | -14.0   -13.0   16.0 |   -12.0   13.0 |   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   15.0   17.0   19.0   -14.0   -13.0   -12.0   13.0   16.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 0      mid: 4       right: 9
MERGE: | -18.0   -16.0   15.0   17.0   19.0 |   -14.0   -13.0   -12.0   13.0   16.0 |   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   11.0   -10.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 10     mid: 10      right: 11
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   | 11.0 |   -10.0 |   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   11.0   9.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 10     mid: 11      right: 12
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   | -10.0   11.0 |   9.0 |   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   9.0   11.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 13     mid: 13      right: 14
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   9.0   11.0   | -8.0 |   3.0 |   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   9.0   11.0   -8.0   3.0   -2.0   -1.0   0.0   7.0   9.0
 left: 10     mid: 12      right: 14
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   | -10.0   9.0   11.0 |   -8.0   3.0 |   -2.0   -1.0   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   7.0   9.0
 left: 15     mid: 15      right: 16
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   | -2.0 |   -1.0 |   0.0   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   7.0   9.0
 left: 15     mid: 16      right: 17
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   | -2.0   -1.0 |   0.0 |   7.0   9.0
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   7.0   9.0
 left: 18     mid: 18      right: 19
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   | 7.0 |   9.0 |
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   7.0   9.0
 left: 15     mid: 17      right: 19
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   | -2.0   -1.0   0.0 |   7.0   9.0 |
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   3.0   9.0   11.0   -2.0   -1.0   0.0   7.0   9.0
 left: 10     mid: 14      right: 19
MERGE: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   | -10.0   -8.0   3.0   9.0   11.0 |   -2.0   -1.0   0.0   7.0   9.0 |
SORT: -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0   -10.0   -8.0   -2.0   -1.0   0.0   3.0   7.0   9.0   9.0   11.0
 left: 0      mid: 9       right: 19
MERGE: | -18.0   -16.0   -14.0   -13.0   -12.0   13.0   15.0   16.0   17.0   19.0 |   -10.0   -8.0   -2.0   -1.0   0.0   3.0   7.0   9.0   9.0   11.0 |
Mang da sap xep: -18.0   -16.0   -14.0   -13.0   -12.0   -10.0   -8.0   -2.0   -1.0   0.0   3.0   7.0   9.0   9.0   11.0   13.0   15.0   16.0   17.0   19.0
 -- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo ...)   ✕

Total:	16567	
ALU:	7878	48%
Jump:	1217	7%
Branch:	2364	14%
Memory:	814	5%
Other:	4294	26%

Tool Control

Disconnect from MIPS | Reset | Close
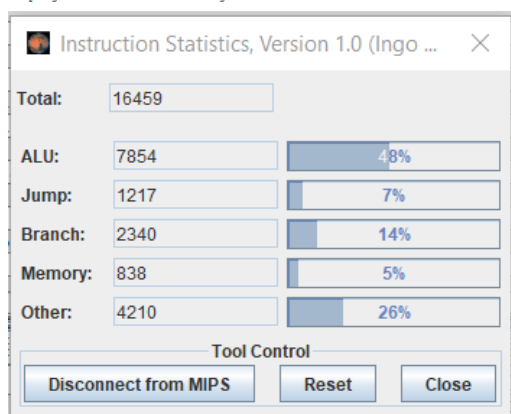
2.4 Testcase 4

Mảng đầu vào đã được sắp xếp là các số nguyên dương từ 1 đến 20

```
Mang ban dau: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 0         mid: 0        right: 1
MERGE: | 1.0 |     2.0 |    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 0         mid: 1        right: 2
MERGE: | 1.0    2.0 |    3.0 |    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 3         mid: 3        right: 4
MERGE: 1.0    2.0    3.0    | 4.0 |     5.0 |    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 0         mid: 2        right: 4
MERGE: | 1.0    2.0    3.0 |    4.0    5.0 |    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 5         mid: 5        right: 6
MERGE: 1.0    2.0    3.0    4.0    5.0    | 6.0 |    7.0 |    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 5         mid: 6        right: 7
MERGE: 1.0    2.0    3.0    4.0    5.0    | 6.0    7.0 |    8.0 |    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 8         mid: 8        right: 9
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    | 9.0 |    10.0 |    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 5         mid: 7        right: 9
MERGE: 1.0    2.0    3.0    4.0    5.0    | 6.0    7.0    8.0 |    9.0    10.0 |    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 0         mid: 4        right: 9
MERGE: | 1.0    2.0    3.0    4.0    5.0 |    6.0    7.0    8.0    9.0    10.0 |    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 10        mid: 10       right: 11
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    | 11.0 |    12.0 |    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 10        mid: 11       right: 12
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    | 11.0    12.0 |    13.0 |    14.0    15.0    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 13        mid: 13       right: 14
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    | 14.0 |    15.0 |    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 10        mid: 12       right: 14
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    | 11.0    12.0    13.0 |    14.0    15.0 |    16.0    17.0    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 15        mid: 15       right: 16
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    | 16.0 |    17.0 |    18.0    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 15        mid: 16       right: 17
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    | 16.0    17.0 |    18.0 |    19.0    20.0
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 18        mid: 18       right: 19
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    | 19.0 |    20.0 |
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 15        mid: 17       right: 19
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    | 16.0    17.0    18.0 |    19.0    20.0 |
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 10        mid: 14       right: 19
MERGE: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    | 11.0    12.0    13.0    14.0    15.0 |    16.0    17.0    18.0    19.0    20.0 |
SORT: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
 left: 0         mid: 9        right: 19
MERGE: | 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0 |    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0 |
Mang da sap xep: 1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0
-- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo ...)

Total:	16459
ALU:	7854	48%
Jump:	1217	7%
Branch:	2340	14%
Memory:	838	5%
Other:	4210	26%

Tool Control

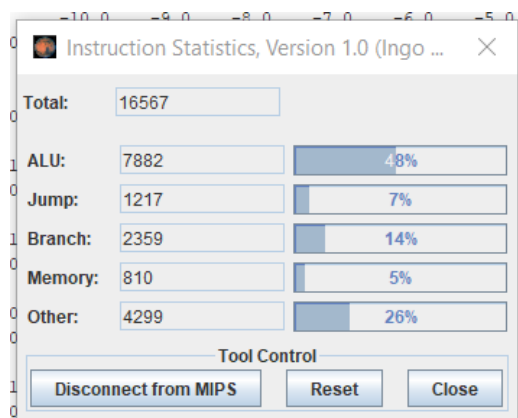[Disconnect from MIPS] [Reset] [Close]

2.5 Testcase 5

Mảng đầu vào ngẫu nhiên có cả số nguyên âm, nguyên dương.

```
Mang ban dau: 20.0    -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: 20.0    -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 0           mid: 0          right: 1
MERGE:  | 20.0 |        -19.0 |     -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   20.0    -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 0           mid: 1          right: 2
MERGE:  | -19.0   20.0 |    -18.0 |   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   20.0    -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 3           mid: 3          right: 4
MERGE: -19.0   -18.0   20.0       | -17.0 |      -16.0 |   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   20.0    -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 0           mid: 2          right: 4
MERGE:  | -19.0   -18.0   20.0 |     -17.0   -16.0 |   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 5           mid: 5          right: 6
MERGE: -19.0   -18.0   -17.0   -16.0   20.0       | -15.0 |      -14.0 |   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 5           mid: 6          right: 7
MERGE: -19.0   -18.0   -17.0   -16.0   20.0       | -15.0   -14.0 |    -13.0 |   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 8           mid: 8          right: 9
MERGE: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0     | -12.0 |      -11.0 |   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 5           mid: 7          right: 9
MERGE: -19.0   -18.0   -17.0   -16.0   20.0       | -15.0   -14.0   -13.0 |    -12.0   -11.0 |   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   20.0    -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 0           mid: 4          right: 9
MERGE:  | -19.0   -18.0   -17.0   -16.0   20.0 |     -15.0   -14.0   -13.0   -12.0   -11.0 |   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 10          mid: 10         right: 11
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0       | -10.0 |      -9.0 |   -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 10          mid: 11         right: 12
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0       | -10.0   -9.0 |    -8.0 |   -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 13          mid: 13         right: 14
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0      | -7.0 |      -6.0 |   -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 10          mid: 12         right: 14
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0       | -10.0   -9.0    -8.0 |   -7.0    -6.0 |   -5.0    -4.0    -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 15          mid: 15         right: 16
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0      | -5.0 |      -4.0 |   -3.0    -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 15          mid: 16         right: 17
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0      | -5.0   -4.0 |    -3.0 |   -2.0    -1.0
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 18          mid: 18         right: 19
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0      | -2.0 |      -1.0 |
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 15          mid: 17         right: 19
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0      | -5.0   -4.0   -3.0 |    -2.0   -1.0 |
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 10          mid: 14         right: 19
MERGE: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0       | -10.0   -9.0    -8.0    -7.0    -6.0 |   -5.0    -4.0    -3.0    -2.0    -1.0 |
SORT: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0    -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0
 left: 0           mid: 9          right: 19
MERGE:  | -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   20.0 |   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0 |
Mang da sap xep: -19.0   -18.0   -17.0   -16.0   -15.0   -14.0   -13.0   -12.0   -11.0   -10.0   -9.0    -8.0    -7.0    -6.0    -5.0    -4.0    -3.0    -2.0    -1.0    20.0
-- program is finished running --
```


Instruction Statistics, Version 1.0 (Ingo ...		
Total:	16567	
ALU:	7882	48%
Jump:	1217	7%
Branch:	2359	14%
Memory:	810	5%
Other:	4299	26%

Tool Control

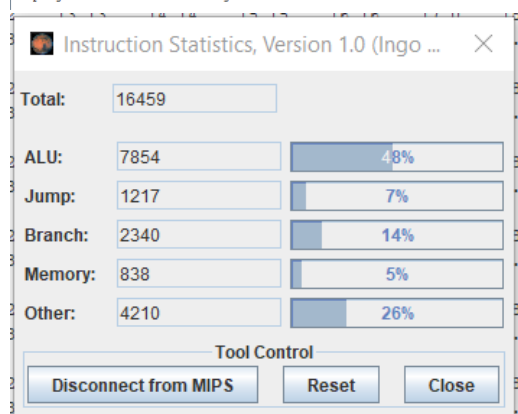| Disconnect from MIPS | Reset | Close |

2.6 Testcase 6

Mảng đầu vào ngẫu nhiên là các số thực.

```
Mang ban dau: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 0       mid: 0       right: 1
MERGE: | 1.1 |   2.2 |    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 0       mid: 1       right: 2
MERGE: | 1.1   2.2 |    3.3 |    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 3       mid: 3       right: 4
MERGE: 1.1    2.2    3.3    | 4.4 |    5.5 |    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 0       mid: 2       right: 4
MERGE: | 1.1   2.2   3.3 |    4.4   5.5 |    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 5       mid: 5       right: 6
MERGE: 1.1    2.2    3.3    4.4    5.5    | 6.6 |    7.7 |    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 5       mid: 6       right: 7
MERGE: 1.1    2.2    3.3    4.4    5.5    | 6.6   7.7 |    8.8 |    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 8       mid: 8       right: 9
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    | 9.9 |    10.1 |    11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 5       mid: 7       right: 9
MERGE: 1.1    2.2    3.3    4.4    5.5    | 6.6   7.7   8.8 |    9.9   10.1 |    11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 0       mid: 4       right: 9
MERGE: | 1.1   2.2   3.3   4.4   5.5 |    6.6    7.7    8.8    9.9    10.1 |    11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 10      mid: 10      right: 11
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   | 11.11 |    12.12 |    13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 10      mid: 11      right: 12
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   | 11.11  12.12 |    13.13 |    14.14  15.15  16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 13      mid: 13      right: 14
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13   | 14.14 |    15.15 |    16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 10      mid: 12      right: 14
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   | 11.11  12.12  13.13 |    14.14  15.15 |    16.16  17.0   18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 15      mid: 15      right: 16
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15    | 16.16 |    17.0 |    18.0   19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 15      mid: 16      right: 17
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15    | 16.16   17.0 |    18.0 |    19.0   20.0
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 18      mid: 18      right: 19
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   | 19.0 |    20.0 |
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 15      mid: 17      right: 19
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15    | 16.16   17.0   18.0 |    19.0   20.0 |
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 10      mid: 14      right: 19
MERGE: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   | 11.11  12.12  13.13  14.14  15.15 |    16.16  17.0   18.0   19.0   20.0 |
SORT: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
 left: 0       mid: 9       right: 19
MERGE: | 1.1   2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1 |    11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0 |
Mang da sap xep: 1.1    2.2    3.3    4.4    5.5    6.6    7.7    8.8    9.9    10.1   11.11  12.12  13.13  14.14  15.15  16.16  17.0   18.0   19.0   20.0
-- program is finished running --
```
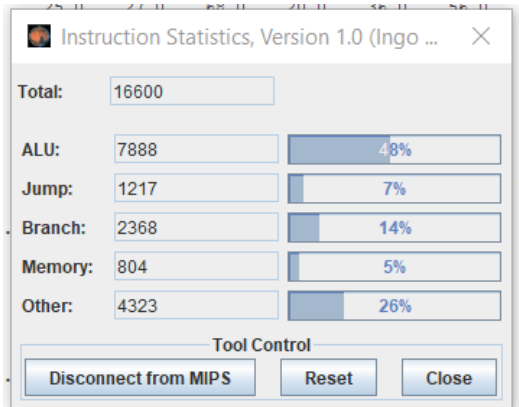
Instruction Statistics, Version 1.0 (Ingo ...) ✕

Total:	16459	
ALU:	7854	48%
Jump:	1217	7%
Branch:	2340	14%
Memory:	838	5%
Other:	4210	26%

Tool Control

Disconnect from MIPS	Reset	Close

2.7 Testcase 7

Mảng đầu vào ngẫu nhiên với các số nguyên nằm trong khoảng $(0, 100]$
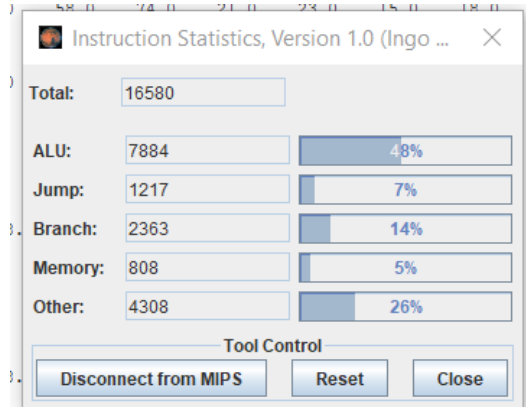
```
Mang ban dau: 100.0    10.0    3.0    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 100.0    10.0    3.0    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 0         mid: 0       right: 1
MERGE: | 100.0 |    10.0 |    3.0    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 10.0    100.0    3.0    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 0         mid: 1       right: 2
MERGE: | 10.0    100.0 |    3.0 |    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    100.0    58.0    13.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 3         mid: 3       right: 4
MERGE: 3.0    10.0    100.0    | 58.0 |    13.0 |    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    100.0    13.0    58.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 0                     mid: 2       right: 4
MERGE: | 3.0    10.0    100.0 |    13.0    58.0 |    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    58.0    100.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 5         mid: 5       right: 6
MERGE: 3.0    10.0    13.0    58.0    100.0    | 15.0 |    47.0 |    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    58.0    100.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 5         mid: 6       right: 7
MERGE: 3.0    10.0    13.0    58.0    100.0    | 15.0    47.0 |    59.0 |    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    58.0    100.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 8         mid: 8       right: 9
MERGE: 3.0    10.0    13.0    58.0    100.0    15.0    47.0    59.0    | 13.0 |    15.0 |    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    58.0    100.0    15.0    47.0    59.0    13.0    15.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 5         mid: 7       right: 9
MERGE: 3.0    10.0    13.0    58.0    100.0    | 15.0    47.0    59.0 |    13.0    15.0 |    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    58.0    100.0    13.0    15.0    15.0    47.0    59.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 0         mid: 4       right: 9
MERGE: | 3.0    10.0    13.0    58.0    100.0 |    13.0    15.0    15.0    47.0    59.0 |    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 10        mid: 10      right: 11
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    | 18.0 |    25.0 |    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 10        mid: 11      right: 12
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    | 18.0    25.0 |    27.0 |    68.0    20.0    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    25.0    27.0    68.0    20.0    36.0    56.0    58.0    54.0    24.0
 left: 13        mid: 13      right: 14
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    25.0    27.0    | 68.0 |    20.0 |    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    25.0    27.0    20.0    68.0    36.0    56.0    58.0    54.0    24.0
 left: 10        mid: 12      right: 14
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    | 18.0    25.0    27.0 |    20.0    68.0 |    36.0    56.0    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    36.0    56.0    58.0    54.0    24.0
 left: 15        mid: 15      right: 16
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    | 36.0 |    56.0 |    58.0    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    36.0    56.0    58.0    54.0    24.0
 left: 15        mid: 16      right: 17
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    | 36.0    56.0 |    58.0 |    54.0    24.0
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    36.0    56.0    58.0    54.0    24.0
 left: 18        mid: 18      right: 19
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    36.0    56.0    58.0    | 54.0 |    24.0 |
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    36.0    56.0    58.0    24.0    54.0
 left: 15        mid: 17      right: 19
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    | 36.0    56.0    58.0 |    24.0    54.0 |
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    25.0    27.0    68.0    24.0    36.0    54.0    56.0    58.0
 left: 10        mid: 14      right: 19
MERGE: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    | 18.0    20.0    25.0    27.0    68.0 |    24.0    36.0    54.0    56.0    58.0 |
SORT: 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0    18.0    20.0    24.0    25.0    27.0    36.0    54.0    56.0    58.0    68.0
 left: 0         mid: 9       right: 19
MERGE: | 3.0    10.0    13.0    13.0    15.0    15.0    47.0    58.0    59.0    100.0 |    18.0    20.0    24.0    25.0    27.0    36.0    54.0    56.0    58.0    68.0 |
Mang da sap xep: 3.0    10.0    13.0    13.0    15.0    15.0    18.0    20.0    24.0    25.0    27.0    36.0    47.0    54.0    56.0    58.0    58.0    59.0    68.0    100.0
-- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo ...)

Total:	16600	
ALU:	7888	48%
Jump:	1217	7%
Branch:	2368	14%
Memory:	804	5%
Other:	4323	26%

Tool Control

Disconnect from MIPS   Reset   Close

2.8 Testcase 8

Mảng đầu vào ngẫu nhiên với các số nguyên nằm trong khoảng $(0, 100)$

```
Mang ban dau: 15.0   58.0   36.0   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   58.0   36.0   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 0         mid: 0        right: 1
MERGE: | 15.0 |      58.0 |   36.0   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   58.0   36.0   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 0         mid: 1        right: 2
MERGE: | 15.0   58.0 |   36.0 |   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   36.0   58.0   47.0   20.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 3         mid: 3        right: 4
MERGE: 15.0   36.0   58.0     | 47.0 |      20.0 |   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   36.0   58.0   20.0   47.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 0         mid: 2        right: 4
MERGE: | 15.0   36.0   58.0 |   20.0   47.0 |   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   36.0   47.0   58.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 5         mid: 5        right: 6
MERGE: 15.0   20.0   36.0   47.0   58.0     | 25.0 |   29.0 |   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   36.0   47.0   58.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 5         mid: 6        right: 7
MERGE: 15.0   20.0   36.0   47.0   58.0     | 25.0   29.0 |   84.0 |   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   36.0   47.0   58.0   25.0   29.0   84.0   91.0   26.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 8         mid: 8        right: 9
MERGE: 15.0   20.0   36.0   47.0   58.0   25.0   29.0   84.0     | 91.0 |   26.0 |   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   36.0   47.0   58.0   25.0   29.0   84.0   26.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 5         mid: 7        right: 9
MERGE: 15.0   20.0   36.0   47.0   58.0     | 25.0   29.0   84.0 |   26.0   91.0 |   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   36.0   47.0   58.0   25.0   26.0   29.0   84.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 0         mid: 4        right: 9
MERGE: | 15.0   20.0   36.0   47.0   58.0 |   25.0   26.0   29.0   84.0   91.0 |   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 10        mid: 10       right: 11
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0     | 34.0 |   58.0 |   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 10        mid: 11       right: 12
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0     | 34.0   58.0 |   74.0 |   21.0   23.0   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 13        mid: 13       right: 14
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   34.0   58.0   74.0     | 21.0 |      23.0 |   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   34.0   58.0   74.0   21.0   23.0   15.0   18.0   19.0   54.0   50.0
 left: 10        mid: 12       right: 14
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0     | 34.0   58.0   74.0 |   21.0   23.0 |   15.0   18.0   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0   54.0   50.0
 left: 15        mid: 15       right: 16
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0     | 15.0 |      18.0 |   19.0   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0   54.0   50.0
 left: 15        mid: 16       right: 17
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0     | 15.0   18.0 |   19.0 |   54.0   50.0
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0   54.0   50.0
 left: 18        mid: 18       right: 19
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0     | 54.0 |      50.0 |
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0   50.0   54.0
 left: 15        mid: 17       right: 19
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0     | 15.0   18.0   19.0 |   50.0   54.0 |
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   21.0   23.0   34.0   58.0   74.0   15.0   18.0   19.0   50.0   54.0
 left: 10        mid: 14       right: 19
MERGE: 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0     | 21.0   23.0   34.0   58.0   74.0 |   15.0   18.0   19.0   50.0   54.0 |
SORT:  15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0   15.0   18.0   19.0   21.0   23.0   34.0   50.0   54.0   58.0   74.0
 left: 0         mid: 9        right: 19
MERGE: | 15.0   20.0   25.0   26.0   29.0   36.0   47.0   58.0   84.0   91.0 |   15.0   18.0   19.0   21.0   23.0   34.0   50.0   54.0   58.0   74.0 |
Mang da sap xep: 15.0   15.0   18.0   19.0   20.0   21.0   23.0   25.0   26.0   29.0   34.0   36.0   47.0   50.0   54.0   58.0   58.0   74.0   84.0   91.0
-- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo ... ✕

Total:	16580	
ALU:	7884	48%
Jump:	1217	7%
Branch:	2363	14%
Memory:	808	5%
Other:	4308	26%

Tool Control

Disconnect from MIPS   Reset   Close

2.9 Testcase 9

Mảng đầu vào là các số trong khoảng $[-10, 10]$

2.10 Testcase 10

Mảng đầu vào là các số ngẫu nhiên trong khoảng $[-99, 99]$

```
UnsortedArray:11.0  22.0  33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  22.0  33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 0        Mid: 0        Right: 1
MERGE: | 11.0 |    22.0   33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  22.0  33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 0        Mid: 1        Right: 2
MERGE: | 11.0   22.0 |   33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  22.0  33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 3        Right: 4
MERGE: 11.0  22.0  33.0  | 14.0 |  41.0 |  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  22.0  33.0  14.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 0        Mid: 2        Right: 4
MERGE: | 11.0   22.0   33.0 |  14.0  41.0 |  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  14.0  22.0  33.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 5        Mid: 5        Right: 6
MERGE: 11.0  14.0  22.0  33.0  41.0  | 25.0 |  52.0 |  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  14.0  22.0  33.0  41.0  25.0  52.0  36.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 5        Mid: 6        Right: 7
MERGE: 11.0  14.0  22.0  33.0  41.0  | 25.0   52.0 |  36.0 |  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  14.0  22.0  33.0  41.0  25.0  36.0  52.0  63.0  -77.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 8        Mid: 8        Right: 9
MERGE: 11.0  14.0  22.0  33.0  41.0  25.0  36.0  52.0  | 63.0 |   -77.0 |  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  14.0  22.0  33.0  41.0  25.0  36.0  52.0  -77.0  63.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 5        Mid: 7        Right: 9
MERGE: 11.0  14.0  22.0  33.0  41.0  | 25.0   36.0   52.0 |  -77.0  63.0 |  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: 11.0  14.0  22.0  33.0  41.0  -77.0  25.0  36.0  52.0  63.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 0        Mid: 4        Right: 9
MERGE: | 11.0   14.0   22.0   33.0   41.0 |  -77.0  25.0  36.0  52.0  63.0 |  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -88.0  -99.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 10       Mid: 10       Right: 11
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  | -88.0 |   -99.0 |  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -88.0  -96.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 10       Mid: 11       Right: 12
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  | -99.0   -88.0 |  -96.0 |  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -69.0  -85.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 13       Mid: 13       Right: 14
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  | -69.0 |   -85.0 |  -58.0  -74.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 10       Mid: 12       Right: 14
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  | -99.0   -96.0   -88.0 |  -85.0  -69.0 |  -58.0  -74.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -58.0  -74.0  -47.0  0.0  1.0
 Left: 15       Mid: 15       Right: 16
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  | -58.0 |   -74.0 |  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -74.0  -58.0  -47.0  0.0  1.0
 Left: 15       Mid: 16       Right: 17
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  | -74.0   -58.0 |  -47.0 |  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -74.0  -58.0  -47.0  0.0  1.0
 Left: 18       Mid: 18       Right: 19
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -74.0  -58.0  -47.0  | 0.0 |   1.0 |
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -74.0  -58.0  -47.0  0.0  1.0
 Left: 15       Mid: 17       Right: 19
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  | -74.0   -58.0   -47.0 |  0.0  1.0 |
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -69.0  -74.0  -58.0  -47.0  0.0  1.0
 Left: 10       Mid: 14       Right: 19
MERGE: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  | -99.0   -96.0   -88.0   -85.0   -69.0 |  -74.0  -58.0  -47.0  0.0  1.0
SORT: -77.0  11.0  14.0  22.0  25.0  33.0  36.0  41.0  52.0  63.0  -99.0  -96.0  -88.0  -85.0  -74.0  -69.0  -58.0  -47.0  0.0  1.0
 Left: 0        Mid: 9        Right: 19
MERGE: | -77.0   11.0   14.0   22.0   25.0   33.0   36.0   41.0   52.0   63.0 |  -99.0   -96.0   -88.0   -85.0   -74.0   -69.0   -58.0   -47.0   0.0   1.0 |
SortedArray:   -99.0   -96.0   -88.0   -85.0   -77.0   -74.0   -69.0   -58.0   -47.0   0.0   1.0   11.0   14.0   22.0   25.0   33.0   36.0   41.0   52.0   63.0
-- program is finished running --
```

Instruction Statistics, Version 1.0 (Ingo Kofler)

Total:	16481
ALU:	7867	48%
Jump:	1217	7%
Branch:	2354	14%
Memory:	822	5%
Other:	4221	26%

Tool Control

Disconnect from MIPS   Reset   Close