



Computer Architecture

HW1: RARS Simulator

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Due: 2022/10/10 23:59 (UTC+8)

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Outline

- ◆ RARS: RISC-V Simulator
- ◆ GUI of RARS
- ◆ HW1-1 Sort Procedure
- ◆ HW1-2 Salt-and-Pepper noise denoiser with median filter
- ◆ Submission
- ◆ Rules



RARS: RISC-V Simulator

- ◆ An open source RISC-V assembler and runtime simulator
- ◆ Support riscv32 and riscv64 on Windows/Mac/Linux
- ◆ Download the .jar file here:
<https://github.com/TheThirdOne/rars/releases/tag/continuous>

Continuous build Latest Compare

TheThirdOne released this 28 Jun 2022 continuous 27a7c1f

continuous

Add .global as alias for .globl

▼ **Assets** 3

rars_27a7c1f.jar	1.77 MB	28 Jun 2022
Source code (zip)		28 Jun 2022
Source code (tar.gz)		28 Jun 2022



RARS: RISC-V Simulator

- ◆ To launch .jar file, make sure you install java
- ◆ <https://www.java.com/en/download/>

Download Java

By downloading Java you acknowledge that you have read and accepted the terms of the
Oracle Technology Network License Agreement for Oracle Java SE

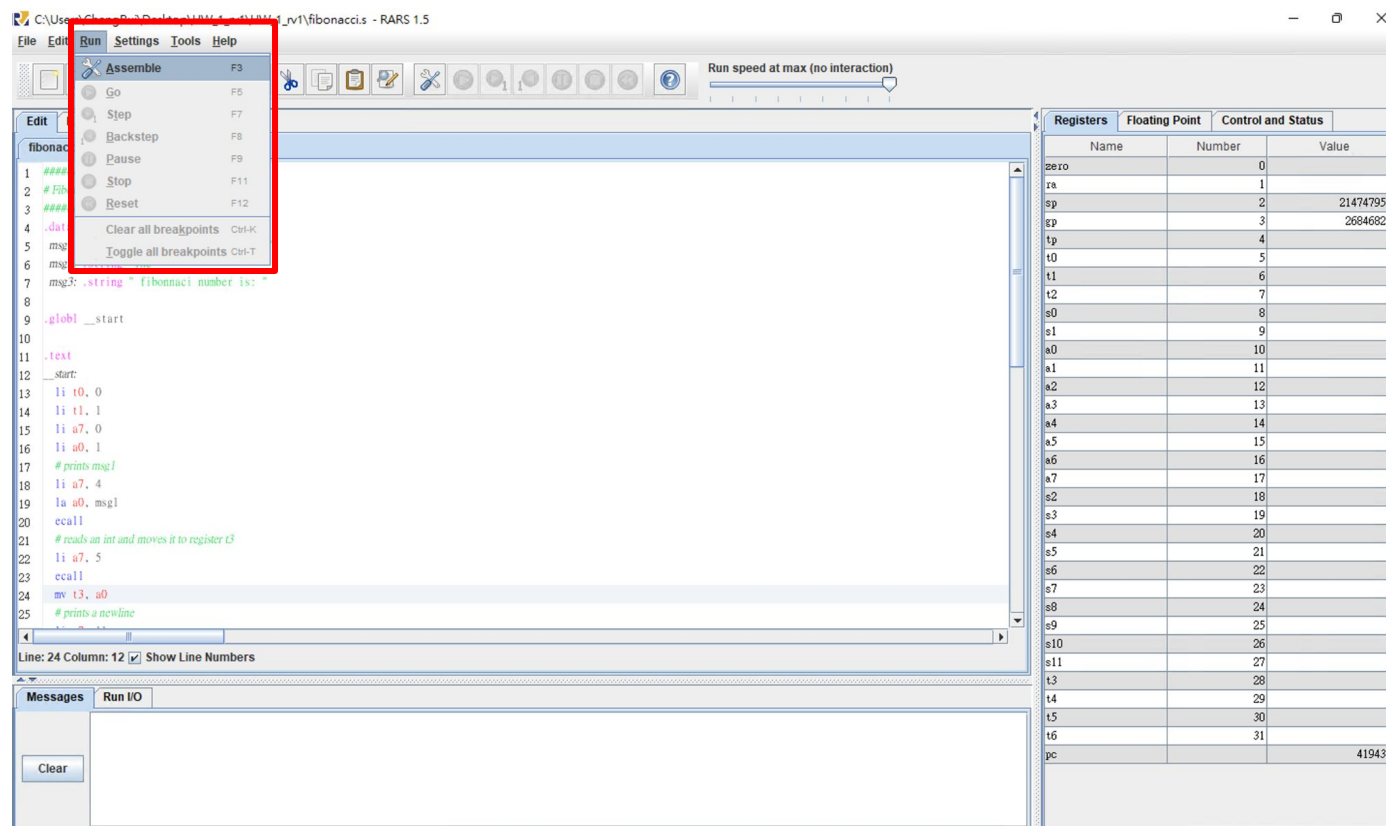
- ◆ Click the .jar file to open it

 rars_27a7c1f.jar	2022/9/15 下午 05:17	Executable Jar File	1,812 KB
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GUI of RARS

- ◆ Open a file
 - ◆ File -> Open
- ◆ Run the code
 - ◆ Run -> Assemble





GUI of RARS

File Edit Run Settings Tools Help

Run/Step/Backstep/Pause/Stop/Reset

Run speed at max (no interaction)

Control the speed of simulation

fibonacci.s

```
1 #####
2 # Fibonacci Example #
3 #####
4 .data
5 msg1: .string "Please enter a number: "
6 msg2: .string "The "
7 msg3: .string " fibonacci number is: "
8
9 .globl __start
10
11 .text
12 __start:
13     li t0, 0
14     li t1, 1
15     li a7, 0
16     li a0, 1
17     # prints msg1
18     li a7, 4
19     la a0, msg1
20     ecall
21     # reads an int and moves it to register t3
22     li a7, 5
23     ecall
24     mv t3, a0
25     # prints a newline
```

Line: 1 Column: 22 ☒ Show Line Numbers

Registers Floating Point Control and Status

Name	Number	Value
zero	0	0
ra	1	0
sp	2	2147479548
gp	3	268468224
tp	4	0
t0	5	0
t1	6	0
t2	7	0
s0	8	0
s1	9	0
a0	10	0
a1	11	0
a2	12	0
a3	13	0
a4	14	0
a5	15	0
a6	16	0
a7	17	0
s2	18	0
s3	19	0
s4	20	0
s5	21	0
s6	22	0
s7	23	0
s8	24	0
s9	25	0
s10	26	0
s11	27	0
t3	28	0
t4	29	0
t5	30	0
t6	31	0
pc		4194304

Messages Run I/O

Please enter a number: 6

The 6 fibonacci number is: 8

-- program is finished running (0) --

Clear

Message window

Type input here



GUI of RARS

File Edit Run Settings Tools Help

Run speed at max (no interaction)

Execute

Text Segment

Bkpt	Address	Code	Basic	Source
<input type="checkbox"/>	4194304	0x00000293	addi x5,x0,0	13: li t0, 0
<input type="checkbox"/>	4194308	0x00100313	addi x6,x0,1	14: li t1, 1
<input type="checkbox"/>	4194312	0x00000893	addi x17,x0,0	15: li a7, 0
<input type="checkbox"/>	4194316	0x00100513	addi x10,x0,1	16: li a0, 1
<input type="checkbox"/>	4194320	0x00400893	addi x17,x0,4	18: li a7, 4
<input type="checkbox"/>	4194324	0x0fc10517	auipc x10,64528	19: la a0, msg1
<input type="checkbox"/>	4194328	0xfec50513	addi x10,x10,-20	
<input type="checkbox"/>	4194332	0x00000073	ecall	20: ecall
<input type="checkbox"/>	4194336	0x00500893	addi x17,x0,5	22: li a7, 5
<input type="checkbox"/>	4194340	0x00000073	ecall	23: ecall

Labels

Label	Address
(global)	
_start	4194304
fibonacci.s	
fib	4194388
finish	4194412
msg1	268500992
msg2	268501016
msg3	268501021

Data Segment

Address	Value (+0)	Value (+4)	Value (+8)	Value (+12)	Value (+16)	Value (+20)	Value (+24)	Value (+28)
268500992	1634036816	1696621939	1919251566	1847615776	1700949365	2112114	543516756	1768300544
268501024	1852731234	543777633	1651340654	1763734117	2112115	0	0	0
268501056	0	0	0	0	0	0	0	0
268501088	0	0	0	0	0	0	0	0
268501120	0	0	0	0	0	0	0	0
268501152	0	0	0	0	0	0	0	0
268501184	0	0	0	0	0	0	0	0
268501216	0	0	0	0	0	0	0	0
268501248	0	0	0	0	0	0	0	0

Registers Floating Point Control and Status

Name	Number	Value
zero	0	0
ra	1	0
sp	2	2147479548
gp	3	268468224
tp	4	0
t0	5	8
t1	6	13
t2	7	13
s0	8	0
s1	9	0
a0	10	8
a1	11	0
a2	12	0
a3	13	0
a4	14	0
a5	15	0
a6	16	0
a7	17	10
s2	18	0
s3	19	0
s4	20	0
s5	21	0
s6	22	0
s7	23	0
s8	24	0
s9	25	0
s10	26	0
s11	27	0
t3	28	0
t4	29	0
t5	30	0
t6	31	0
pc		4194448

Messages Run I/O

Please enter a number: 6

The 6 fibonacci number is: 8

-- program is finished running (0) --

Clear

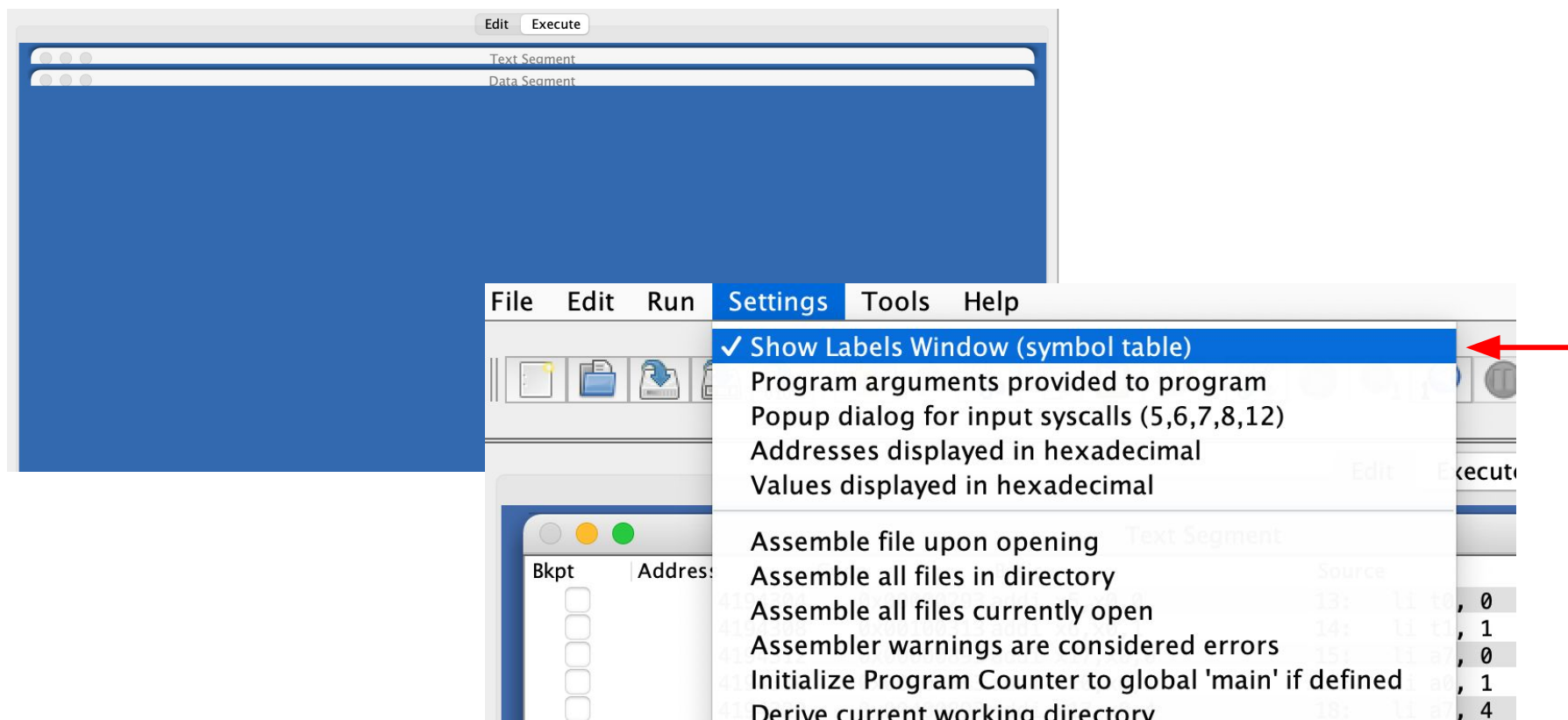
Instruction steps

Data stored in memory



GUI of RARS

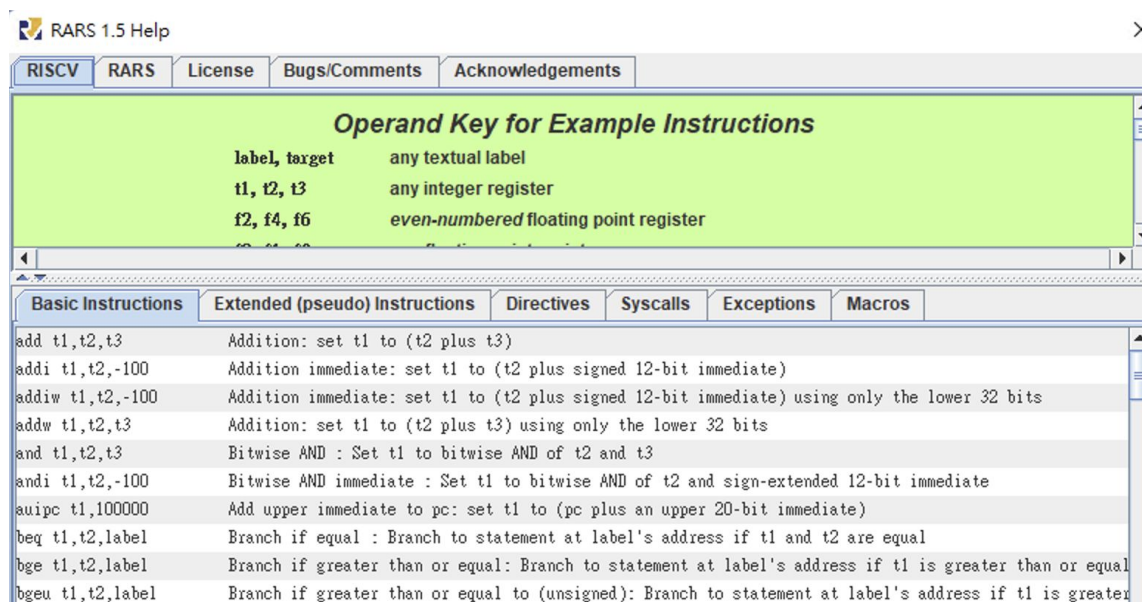
- ◆ If you cannot open Text and Data section window successfully (especially for Mac user)
 - ◆ Settings -> Show Labels Window
 - ◆ Issue: <https://github.com/TheThirdOne/rars/issues/116>





GUI of RARS

- ◆ RARS information
 - ◆ Help -> Help
- ◆ Change to 64-bit RISC-V
 - ◆ Settings -> 64 bit
- ◆ Dump memory
 - ◆ File -> Dump Memory -> Select your preference





HW1-1: Sort Procedure

- ◆ Modify **HW1_1.s** to implement a sorting function
- ◆ Input
 - ◆ An integer array
 - ◆ {10, -2, 4, -7, 6, 9, 3, 1, -5, -8}
- ◆ Output
 - ◆ A sorted array in **ascending order**
- ◆ Useful sorting algorithm
 - ◆ Bubble sort...
- ◆ Submission
 - ◆ Snapshot the sorting result

```
This is HW1_1:
Before sorting:
1 -3 5 2 -4 10 -9 8 -11 23
After sorting:
-11 -9 -4 -3 1 2 5 8 10 23
-- program is finished running (0) --
```

Screenshot example



Template of HW1-1

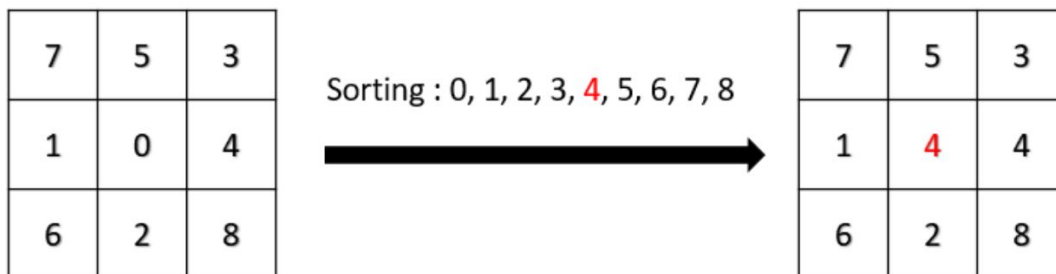
- ◆ The num address is stored in a2
- ◆ The length of num is stored in a3
- ◆ The **output num address** should be stored in **a2**
- ◆ Write your code in the red frame

```
11 main:
12     # Print initiate
13     li a7, 4
14     la a0, str1
15     ecall
16
17     # a2 stores the num address, a3 stores the length of num
18     la a2, num
19     li a3, 10
20     jal prints
21
22     la a2, num
23     li a3, 10
24     jal sort
25
26     # Print result
27     li a7, 4
28     la a0, str2
29     ecall
30
31     la a2, num
32     li a3, 10
33     jal prints
34
35     # End the program
36     li a7, 10
37     ecall
38     #-----Do not modify above text-----
39     sort:
40     ### To Do ###
41
42
43
44     jr ra
45
46
47     #-----Do not modify below text-----
48     # Print function
49     prints:
50     mv t0, zero # for(i=0)
51     # a2 stores the num address, a3 stores the length of num
52     mv t1, a2
```



HW1-2: Denoiser with Median Filter

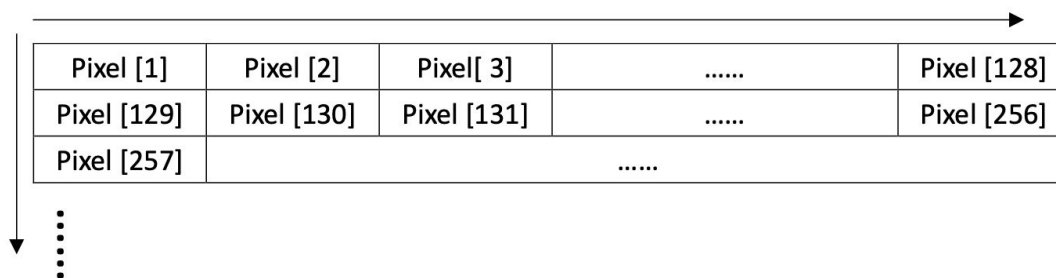
- ◆ Salt-and-pepper noise is an impulse noise caused by sharp and sudden disturbances in an image
 - ◆ Since the noise is whether white or black, it can be denoised by a median filter
- ◆ For a 3x3 median filter, the filter sorts all 9 numbers in the array and replaces the center element with the median of the sorted array





HW1-2: Denoiser with Median Filter

- ◆ Apply 3x3 median filter on a 128x128 an image with salt-and-pepper noise



- ◆ The filter only work on the input image, which means the previous updated pixel won't affect the latter result
- ◆ Do not consider boundary condition, so you don't need to calculate when the center pixel is on or out of the boundaries
 - ◆ 128x128 input image -> 126x126 output image



HW1-2: Denoiser with Median Filter

- ◆ After you finish the median filter operation, please store your output(median) in the output array **data_o**
 - ◆ Do not modify the input array data_i
- ◆ Feel free to use the buffer array **buffer** if you need to store some temporary data

```
# 128*128 input
data_i: .dword 38, 19, 174, 42, 115, 184, 188, 232, 77
data_o: .dword 0:15876 #initiate 15876 dwords with value 0
data_size: .dword 128, 128

buffer: .dword 0:9

.globl main
```



HW1-2: Denoiser with Median Filter

- ◆ Modify **HW1_2.s** to complete your denoising procedure
 - ◆ We also provide two small arrays (7x7 and 10x14) in testing_data.txt for you to debug easier
- ◆ You should dump **memory.txt** for our convenience to verify the answer (input image 128x128 version)
 - ◆ File -> Dump Memory -> Memory Segment(.data) -> Text/Data -> Dump To File... -> memory.txt
 - ◆ Remember to **uncheck Hexadecimal Addresses and Hexadecimal Values** before dumping memory

Address	Value (+0)	Value (+4)	Value (+8)	Value (+12)	Value (+16)	Value (+20)	Value (+24)	Value (+28)
268500992	1936287828	544434464	1597069128	1461729842	543716457	1702521203	706740256	1107951648
268501024	1919903333	670309	1970496850	171603052	167774464	0	162	0
268501056	162	0	166	0	155	0	157	0
268501088	154	0	153	0	156	0	154	0
268501120	158	0	166	0	171	0	172	0
268501152	168	0	147	0	130	0	97	0
268501184	88	0	104	0	105	0	110	0
268501216	104	0	108	0	110	0	109	0
268501248	104	0	109	0	113	0	112	0

0x10010000 (.data) ☐ Hexadecimal Addresses ☐ Hexadecimal Values ☐ ASCII



Dump Memory File

- ◆ Uncheck Hexadecimal Addresses and Hexadecimal Values

Step 1

Edit **Execute**

Text Segment

Bkpt	Address	Code	Basic	Source
<input type="checkbox"/>	4194304	0x00400893	addi x17,x0,4	13: li a7, 4
<input type="checkbox"/>	4194308	0x0fc10517	auipc x10,64528	14: la a0, str1
<input type="checkbox"/>	4194312	0xffc50513	addi x10,x10,-4	
<input type="checkbox"/>	4194316	0x00000073	ecall	15: ecall
<input type="checkbox"/>	4194320	0x0fc10617	auipc x12,64528	18: la a2, num
<input type="checkbox"/>	4194324	0x02860613	addi x12,x12,40	
<input type="checkbox"/>	4194328	0x00a00693	addi x13,x0,10	19: li a3, 10
<input type="checkbox"/>	4194332	0x084000ef	jal x1,132	20: jal prints
<input type="checkbox"/>	4194336	0x0fc10617	auipc x12,64528	22: la a2, num
<input type="checkbox"/>	4194340	0x01860613	addi x12,x12,24	

Labels

Label	Address
(global)	
main	4194304
HW1_1.s	
sort	4194392
for1	4194400
for2	4194412
swap	4194436
exitswap	4194444
exit2	4194452
exit1	4194460
prints	4194464

☒ Data ☒ Text

Data Segment

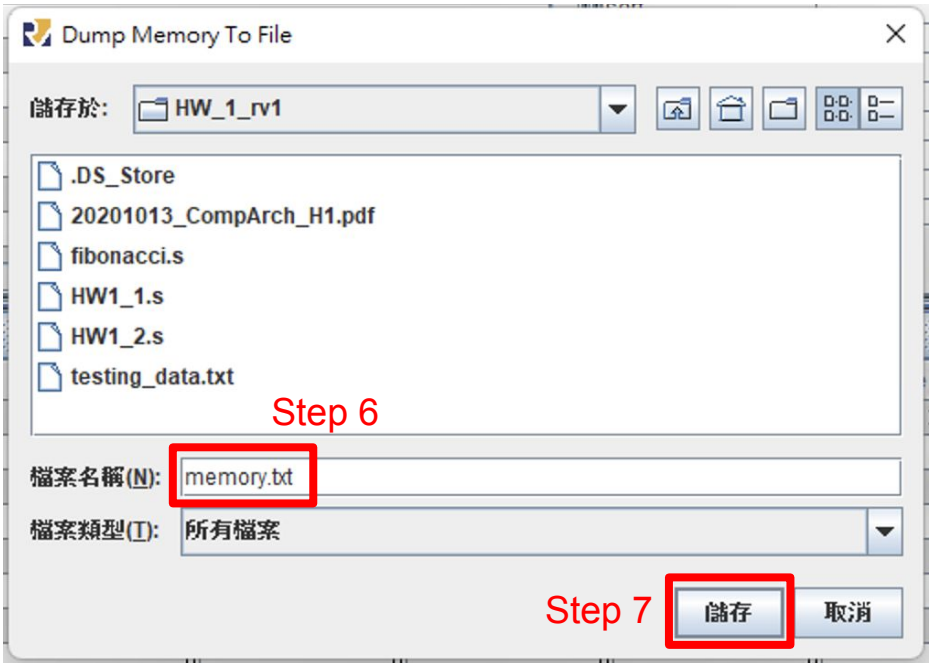
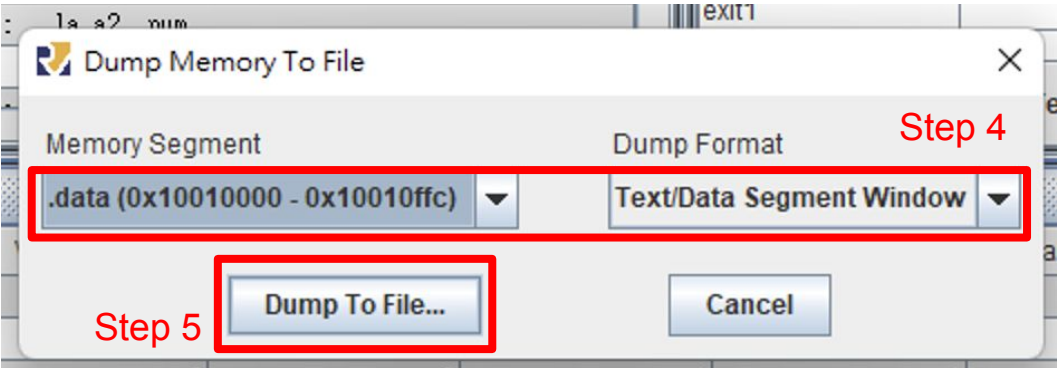
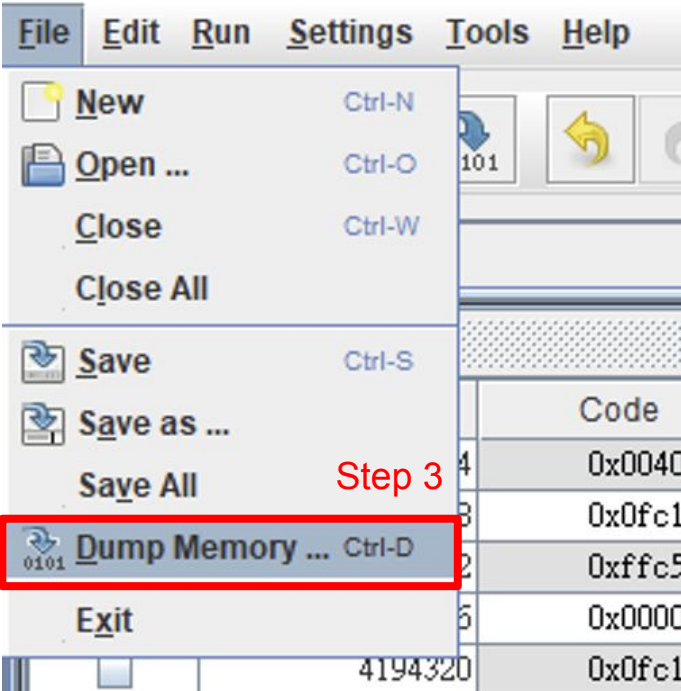
Address	Value (+0)	Value (+4)	Value (+8)	Value (+12)	Value (+16)	Value (+20)	Value (+24)	Value (+28)
268500992	1936287828	544434464	1597069128	1107966513	1919903333	1869815909	1852404850	169884263
268501024	1715538432	544367988	1953656691	979857001	538968074	0	-8	0
268501056	-7	-1	-5	0	-2	-1	1	0
268501088	3	0	4	0	6	0	9	-1
268501120	10	-1	0	0	0	0	0	0
268501152	0	0	0	0	0	0	0	0
268501184	0	0	0	0	0	0	0	0
268501216	0	0	0	0	0	0	0	0
268501248	0	0	0	0	0	0	0	0

0x10010000 (.data) ☐ Hexadecimal Addresses ☐ Hexadecimal Values ☐ ASCII

Step 2



Dump Memory File





Submission

- ◆ HW1-1: snapshot the sorting result on console window and save as **HW1_1.jpg**
- ◆ HW1-2: dump **data** memory into file **memory.txt**
- ◆ If you have trouble in HW1-2, you can write the implementation details in **report.pdf** to get partial credit!



Submission

- ◆ Deadline: **2022/10/10 23:59 (UTC+8)**
 - ◆ No late submission allowed
- ◆ Hand in results on **NTU COOL**
- ◆ Your homework should be copied into a **folder** and packed into a **zip** file with the following **naming rules** (5% penalty for wrong format)
 - ◆ hw1_<student_id>.zip
 - hw1_<student_id>
 - HW1_1.s, HW1_2.s (assembly code)
 - HW1_1.jpg (HW1-1 sorting result screenshot)
 - memory.txt (HW1-2 memory data file)
 - report.pdf (If you can't finish memory.txt)
 - README (If you think you need it)
 - ◆ Ex: hw1_r10943006.zip



Rules

- ◆ You should finish your homework on your own
- ◆ Do **NOT** share your codes or copy other people's codes
- ◆ Do **NOT** modify the input, output, and any provided instructions