PES UNIVERSITY

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Department of Electronics and Communication Engineering

Course Title: RISC-V ARCHITECTURE

Course Code: UE21EC352A

Teacher: PROF. VANAMALA H R

Project Title:

UNDERSTANDING RISC-V ASSEMBLY:

LONGEST COMMON SUBSEQUENCE

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The Longest Common Subsequence (LCS) problem has various real-life applications, and one notable example is in bioinformatics, particularly in the field of DNA sequence analysis.

1. **DNA Sequence Alignment:**
    - **In bioinformatics, scientists often deal with the comparison of DNA sequences from different organisms or individuals. The LCS algorithm can be applied to find the longest common subsequence between two DNA sequences. This information is valuable for understanding genetic similarities and differences between species, studying evolutionary relationships, and identifying common genetic patterns.**
    - **For example, when comparing the DNA of two individuals or species, identifying the longest common subsequence helps highlight regions of similarity in their genetic makeup. This can be crucial for identifying shared genes, understanding evolutionary relationships, and studying the genetic basis of diseases.**

- **LCS algorithms are employed in bioinformatics tools for sequence alignment, where the goal is to find the optimal alignment between two biological sequences, such as DNA or protein sequences. Identifying the longest common subsequence aids in understanding genetic variations, mutations, and functional similarities.**

2. **Version Control Systems:**

- **In software engineering, version control systems (VCS) like Git use algorithms related to LCS to determine the differences between different versions of source code files. The LCS algorithm helps identify the longest common subsequence of lines or characters between two versions, and the differing elements are used to represent changes (additions, deletions, or modifications).**
- **When you commit changes to a code repository, the version control system needs to efficiently identify the changes made compared to the previous version. LCS-based**

algorithms help in this process by identifying the common and differing parts of the code.

- Efficiently computing the LCS is essential for minimizing storage space and optimizing the speed of operations in version control systems.

These applications highlight the versatility and significance of the Longest Common Subsequence problem in diverse fields, ranging from bioinformatics to software engineering. The problem-solving approach used in LCS algorithms has practical implications for solving complex sequence matching problems in various domains.

1. Plagiarism Detection:
    - In the field of academic and content-related writing, plagiarism detection systems use LCS algorithms to identify similarities between documents. By finding the longest common subsequence between two pieces of text, these systems can highlight potential instances of plagiarism or content reuse.
2. Speech Recognition:

- **In speech recognition systems, the LCS algorithm can be employed to compare spoken words or phrases. By finding the longest common subsequence, the system can identify similarities between the recognized speech and a reference vocabulary, aiding in accurate transcription.**

3. **Image Comparison:**
    - **Image processing and computer vision applications use LCS techniques to compare images. The problem can be applied to find the longest common subsequence of pixel values between two images, helping to identify similarities and differences. This is useful in tasks like image recognition and content-based image retrieval.**
4. **Network Traffic Analysis:**
    - **In cybersecurity, analyzing network traffic patterns is crucial for identifying potential security threats. The LCS algorithm can be used to compare sequences of network events or patterns, helping to detect anomalies, intrusions, or malicious activities.**

5. **Recommender Systems:**
    - **In recommender systems for e-commerce or content platforms, LCS algorithms can be used to analyze user behavior sequences. By finding common subsequences of user interactions, these systems can recommend products or content based on users' historical preferences.**
6. **Automatic Summarization:**
    - **In natural language processing and text summarization, the LCS problem can be utilized to identify common phrases or sentences in a set of documents. This can help in generating concise and meaningful summaries by selecting the most relevant content.**
7. **Comparing Biological Sequences (Proteins):**
    - **In addition to DNA sequences, LCS algorithms are applied to compare protein sequences. Analyzing the longest common subsequence of amino acids in proteins is**

crucial for understanding protein structures, functions, and evolutionary relationships.

8. **Code Clone Detection:**
    - **In software engineering, code clone detection involves identifying duplicated or similar code segments in a software project. LCS algorithms can be used to compare code sequences and identify common structures, aiding in the detection of code clones.**

These applications showcase the versatility of the LCS problem-solving approach in diverse domains, emphasizing its usefulness in analyzing and comparing sequences of various types. The underlying principles of LCS algorithms can be adapted to address challenges in different fields where sequence matching is a key task.

SOURCE CODE:

```
.data
.align 4
# test pattern
SequenceA: .string "AKASHRAVIBHAT"
SequenceB: .string "AKASHRGUT"
SASize: .word 13
SBSize: .word 12
str: .string "Found LCS length "
newline: .string "\n"
i: .word 0
j: .word 0
L: .word 1024
.text
.global _start


_start:
```

```
la a0 SequenceA
la a1 SequenceB
lw a2 i
lw a3 j
la a4 L
lw a5 SASize
lw a6 SBSize

jal lcs

#print str
la a0, str
li a7, 4
ecall
#print a0
mv a0 t0
li a7 1
ecall
```

```
    #print \n
    la a0, newline
    li a7, 4
    ecall
    #The values in a7 are set to 1 for the "print integer"
    #system call and 10 for the "exit" system call.

    j end

lcs:

    addi sp, sp, -4
    sw ra, 0(sp) # return address
    addi a2 a2 -1 #set i=-1 first

First_for:
    addi a2 a2 1 #i=i+1
    bgt a2 a5 exit
```

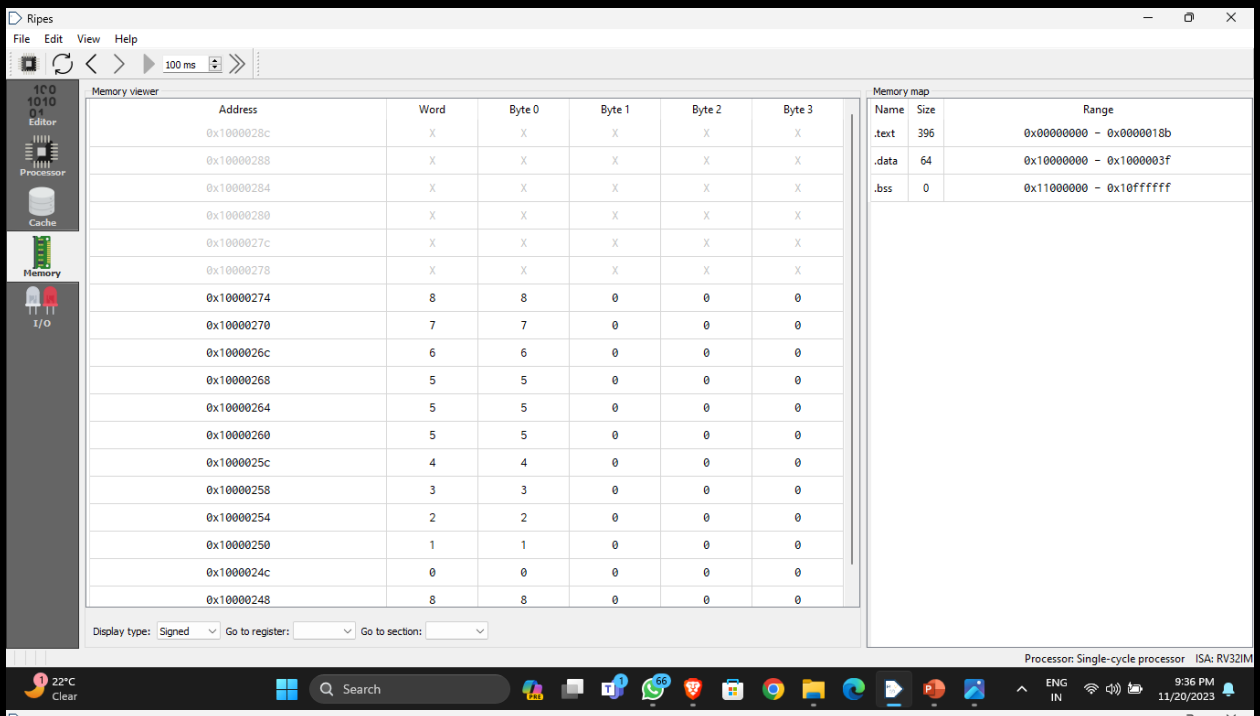
```
    addi a3 x0 0 #set j=0
Second_for:
    #jump to First_for if j > SBSize
    bgt a3 a6 First_for
    #jump to condition one if i=0 ||  j=0
    beq a2 zero condition1
    bne a3 zero condition2
condition1:
    addi t0 a6 1
    mul t0 t0 a2 #t0=(SBSize+1)*i
    add t1 t0 a3 #t1=(SBSize+1)*i+j
    slli t1 t1 2 #t1=((SBSize+1)*i+j)*4 RAW Hazard
    add t1 a4 t1 #t1=((SBSize+1)*i+j)*4+a4
    sw x0 0(t1) #L[i][j]=0
    addi a3 a3 1 #j=j+1
    beq x0 x0 Second_for
condition2:
    addi t2 a2 -1 #t2=i-1
```

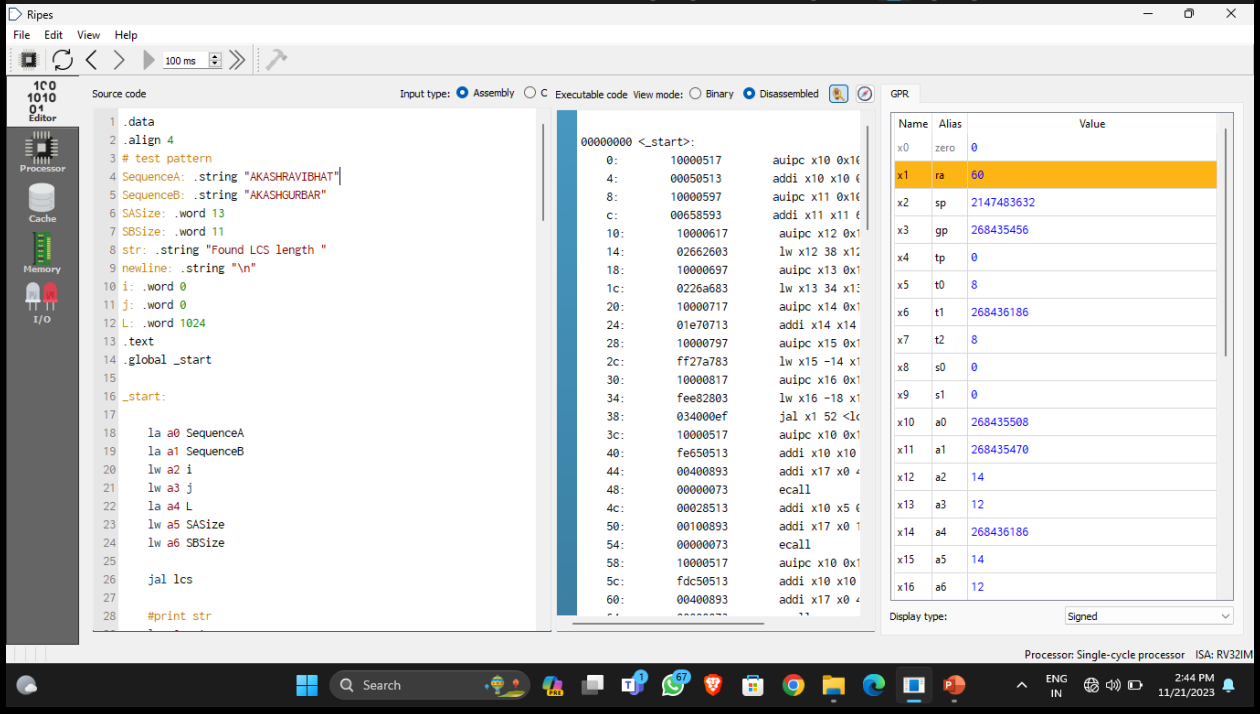
```
    addi t3 a3 -1 #t3=j-1
    add t0 a0 t2 #t0=SequenceA+i-1
    add t1 a1 t3 #t1=SequenceB+j-1
    lb t0 0(t0) #t0=SequenceA[i-1]
    lb t1 0(t1) #t1=SequenceB[j-1]
    bne t0 t1 condition3

    addi t0 a6 1
    mul t0 t0 a2 #t0=(SBSize+1)*i
    add t1 t0 a3 #t1=(SBSize+1)*i+j
    slli t1 t1 2 #t1=((SBSize+1)*i+j)*4 RAW Hazard
    add t1 a4 t1 #t1=[(SBSize+1)*i+j]*4+a4

    addi t0 a6 1
    mul t2 t0 t2 #t2=(SBSize+1)*(i-1)
    add t3 t2 t3 #t3-[(SBSize+1)*(i-1)+(j-1)]
    slli t3 t3 2 #t3=[(SBSize+1)*(i-1)+(j-1)]*4  RAW
Hazard
```

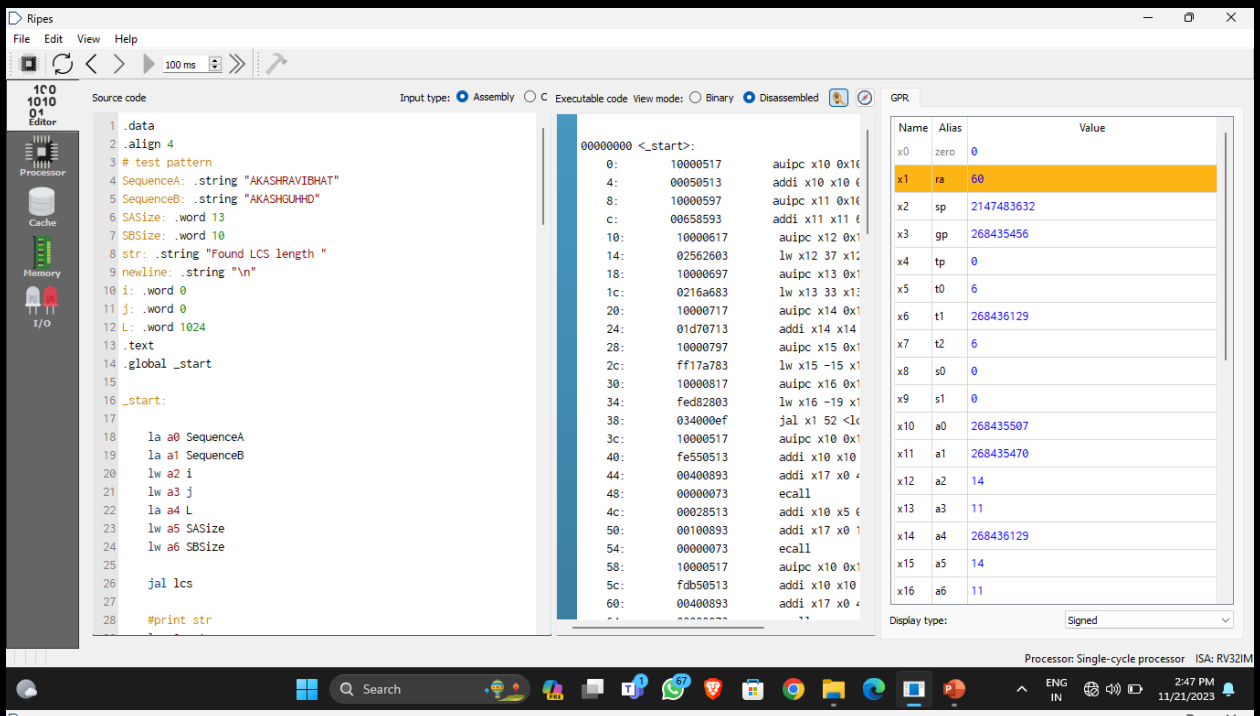
```
    add t3 a4 t3 #t3=[(SBSize+1)*(i-1)+(j-1)]*4+a4
    lw t3 0(t3) #t3=L[i-1][j-1]
    addi t3 t3 1 #t3=t3+1
    sw t3 0(t1) #L[i][j]=L[i-1][j-1]+1

    addi a3 a3 1 #j=j+1
    beq x0 x0 Second_for
condition3:
    addi t0 a6 1 #t0=(SBSize+1)
    mul t0 t0 a2 #t0=(SBSize+1)*i
    add t1 t0 a3 #t1=(SBsize+1)*i+j
    slli t1 t1 2 #t1=((SBSize+1)*i+j)*4 RAW Hazard
    mv t0 t1 #t0=((SBSize+1)*i+j)*4
    add t1 a4 t1 #t1=((SBSize+1)*i+j)*4+a4

    addi t2 a6 1 #t2=(SBSize+1)
    slli t2 t2 2 #t2=(SBSize+1)*4
```

```
    sub t2 t0 t2 #t2=[(SBSize+1)*(i-1)+j]*4  RAW Hazard
    add t2 a4 t2 #t2=[(SBSize+1)*(i-1)+j]*4+a4  WAW Hazard
    lw t2 0(t2) #t2=L[i-1][j]   LOAD Hazard

    addi t4 t0 -4 #t4=[(SBSize+1)*i+(j-1)]*4
    add t4 a4 t4 #t4=[(SBSize+1)*i+(j-1)]*4+a4  WAW Hazard
    lw t4 0(t4) #t4=L[i][j-1]   LOAD Hazard


    sub t5 t2 t4
    bge t5 zero index
    sw t4 0(t1) #L[i][j]=t2=L[i][j-1]
    beq x0 x0 exit_condition3
index:
    sw t2 0(t1) #L[i][j]=t2=L[i-1][j]
```

```
exit_condition3:
    addi a3 a3 1 #j=j+1
    beq x0 x0 Second_forexit:
    addi a5 a5 1
    addi a6 a6 1
    mul t0 a5 a6 #t0=(SASize+1)*(SBSize+1)
    slli t0 t0 2 #t0=(SASize+1)*(SBSize+1)*4
    addi t0 t0 -4 #t0=(SASize+1)*(SBSize+1)*4-4 the last word
   add a4 a4 t0 #a4=a4+t0
    lw a0 0(a4) #a0=L[SASize][SBSize]
    lw   ra, 0(sp) # Reload return address from stack
    add t0 x0 a0
    addi sp, sp, 4 # Restore stack pointer
    jr x1
end:nop
```


Ripes
File Edit View Help
100 ms
Editor
Processor
Cache
Memory
I/O
Memory viewer
Address Word Byte 0 Byte 1 Byte 2 Byte 3
0x1000028c X X X X X
0x10000288 X X X X X
0x10000284 X X X X X
0x10000280 X X X X X
0x1000027c X X X X X
0x10000278 X X X X X
0x10000274 8 8 0 0 0
0x10000270 7 7 0 0 0
0x1000026c 6 6 0 0 0
0x10000268 5 5 0 0 0
0x10000264 5 5 0 0 0
0x10000260 5 5 0 0 0
0x1000025c 4 4 0 0 0
0x10000258 3 3 0 0 0
0x10000254 2 2 0 0 0
0x10000250 1 1 0 0 0
0x1000024c 0 0 0 0 0
0x10000248 8 8 0 0 0
Display type: Signed Go to register: Go to section:
Memory map
Name Size Range
.text 396 0x00000000 - 0x0000018b
.data 64 0x10000000 - 0x1000003f
.bss 0 0x11000000 - 0x10ffffff
Processor: Single-cycle processor ISA: RV32IM
22°C Clear
Search
ENG IN
9:36 PM 11/20/2023

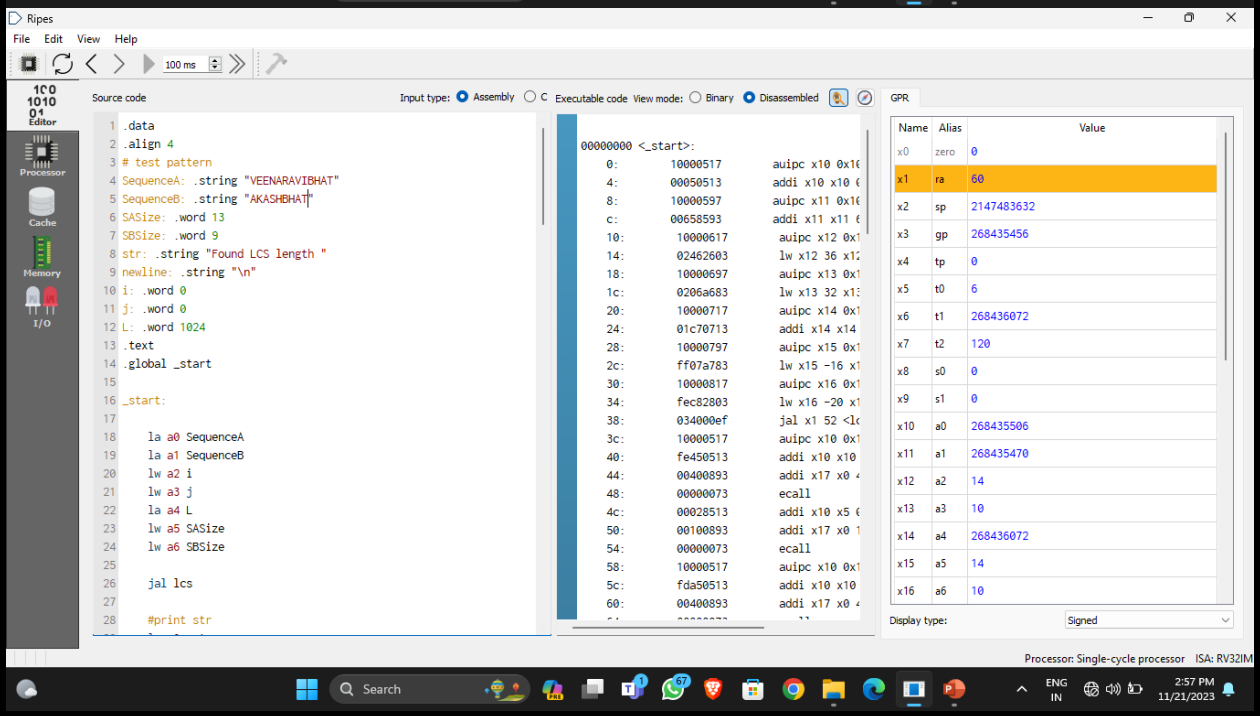

Ripes
File Edit View Help
100 ms
Editor
Processor
Cache
Memory
I/O
Source code
Input type: Assembly C
1 .data
2 .align 4
3 # test pattern
4 SequenceA: .string "AKASHRAVIBHAT"
5 SequenceB: .string "AKASHGURBAR"
6 SASize: .word 13
7 SBSize: .word 11
8 str: .string "Found LCS length "
9 newline: .string "\n"
10 i: .word 0
11 j: .word 0
12 L: .word 1024
13 .text
14 .global _start
15
16 _start:
17
18 la a0 SequenceA
19 la a1 SequenceB
20 lw a2 i
21 lw a3 j
22 la a4 L
23 lw a5 SASize
24 lw a6 SBSize
25
26 jal lcs
27
28 #print str
Executable code View mode: Binary Disassembled
00000000 <_start>:
0: 10000517 auipc x10 0x10
4: 00050513 addi x10 x10 0
8: 10000597 auipc x11 0x10
c: 00658593 addi x11 x11 6
10: 10000617 auipc x12 0x1
14: 02662603 lw x12 38 x12
18: 10000697 auipc x13 0x1
1c: 0226a683 lw x13 34 x13
20: 10000717 auipc x14 0x1
24: 01e70713 addi x14 x14
28: 10000797 auipc x15 0x1
2c: ff27a783 lw x15 -14 x1
30: 10000817 auipc x16 0x1
34: fee82803 lw x16 -18 x1
38: 034000ef jal x1 52 <lc
3c: 10000517 auipc x10 0x1
40: fe650513 addi x10 x10
44: 00400893 addi x17 x0 4
48: 00000073 ecall
4c: 00028513 addi x10 x5 0
50: 00100893 addi x17 x0 1
54: 00000073 ecall
58: 10000517 auipc x10 0x1
5c: fdc50513 addi x10 x10
60: 00400893 addi x17 x0 4
GPR
Name Alias Value
x0 zero 0
x1 ra 60
x2 sp 2147483632
x3 gp 268435456
x4 tp 0
x5 t0 8
x6 t1 268436186
x7 t2 8
x8 s0 0
x9 s1 0
x10 a0 268435508
x11 a1 268435470
x12 a2 14
x13 a3 12
x14 a4 268436186
x15 a5 14
x16 a6 12
Display type: Signed
Processor: Single-cycle processor ISA: RV32IM
Search
ENG IN
2:44 PM 11/21/2023




```
.data
.align 4
# test pattern
SequenceA: .string "AKASHRAVIBHAT"
SequenceB: .string "AKASHGUHHD"
SASize: .word 13
SBSize: .word 10
str: .string "Found LCS length "
newline: .string "\n"
i: .word 0
j: .word 0
L: .word 1024
.text
.global _start

_start:

    la a0 SequenceA
    la a1 SequenceB
    lw a2 i
    lw a3 j
    la a4 L
    lw a5 SASize
    lw a6 SBSize

    jal lcs

    #print str
```

```
00000000 <_start>:
    0:        10000517        auipc x10 0x10
    4:        00050513        addi x10 x10 0
    8:        10000597        auipc x11 0x10
    c:        00658593        addi x11 x11 6
   10:        10000617        auipc x12 0x1
   14:        02562603        lw x12 37 x12
   18:        10000697        auipc x13 0x1
   1c:        0216a683        lw x13 33 x13
   20:        10000717        auipc x14 0x1
   24:        01d70713        addi x14 x14
   28:        10000797        auipc x15 0x1
   2c:        ff17a783        lw x15 -15 x1
   30:        10000817        auipc x16 0x1
   34:        fed82803        lw x16 -19 x1
   38:        034000ef        jal x1 52 <lc
   3c:        10000517        auipc x10 0x1
   40:        fe550513        addi x10 x10
   44:        00400893        addi x17 x0 4
   48:        00000073        ecall
   4c:        00028513        addi x10 x5 0
   50:        00100893        addi x17 x0 1
   54:        00000073        ecall
   58:        10000517        auipc x10 0x1
   5c:        fdb50513        addi x10 x10
   60:        00400893        addi x17 x0 4
```

Name	Alias	Value
x0	zero	0
x1	ra	60
x2	sp	2147483632
x3	gp	268435456
x4	tp	0
x5	t0	6
x6	t1	268436129
x7	t2	6
x8	s0	0
x9	s1	0
x10	a0	268435507
x11	a1	268435470
x12	a2	14
x13	a3	11
x14	a4	268436129
x15	a5	14
x16	a6	11




```
.data
.align 4
# test pattern
SequenceA: .string "VEENARAVIBHAT"
SequenceB: .string "AKASHBHAT"
SASize: .word 13
SBSize: .word 9
str: .string "Found LCS length "
newline: .string "\n"
i: .word 0
j: .word 0
L: .word 1024
.text
.global _start

_start:

    la a0 SequenceA
    la a1 SequenceB
    lw a2 i
    lw a3 j
    la a4 L
    lw a5 SASize
    lw a6 SBSize

    jal lcs

    #print str
```

```
00000000 <_start>:
    0:        10000517        auipc x10 0x10
    4:        00050513        addi x10 x10 0
    8:        10000597        auipc x11 0x10
    c:        00658593        addi x11 x11 6
   10:        10000617        auipc x12 0x1
   14:        02462603        lw x12 36 x12
   18:        10000697        auipc x13 0x1
   1c:        0206a683        lw x13 32 x13
   20:        10000717        auipc x14 0x1
   24:        01c70713        addi x14 x14
   28:        10000797        auipc x15 0x1
   2c:        ff07a783        lw x15 -16 x1
   30:        10000817        auipc x16 0x1
   34:        fec82803        lw x16 -20 x1
   38:        034000ef        jal x1 52 <lc
   3c:        10000517        auipc x10 0x1
   40:        fe450513        addi x10 x10
   44:        00400893        addi x17 x0 4
   48:        00000073        ecall
   4c:        00028513        addi x10 x5 0
   50:        00100893        addi x17 x0 1
   54:        00000073        ecall
   58:        10000517        auipc x10 0x1
   5c:        fda50513        addi x10 x10
   60:        00400893        addi x17 x0 4
```

Name	Alias	Value
x0	zero	0
x1	ra	60
x2	sp	2147483632
x3	gp	268435456
x4	tp	0
x5	t0	6
x6	t1	268436072
x7	t2	120
x8	s0	0
x9	s1	0
x10	a0	268435506
x11	a1	268435470
x12	a2	14
x13	a3	10
x14	a4	268436072
x15	a5	14
x16	a6	10

REFERENCE:

1. **Books:**
    - **"Introduction to Algorithms" by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein.**
    - **"Assembly Language for x86 Processors" by Kip R. Irvine.**
2. **Online Documentation:**
    - **RISC-V ISA specifications: https://riscv.org/specifications/**
3. **Educational Platforms:**
    - **Online programming courses or platforms where assembly programming is taught, such as Coursera, edX, or others.**

THANK YOU!