Project 2: **MIPS Simulator**

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Due: 11:59pm November 24, 2019

1. Description

The goal of this project is to write a simulator program that simulates the MIPS microarchitecture (single cycle execution). You need to model the basic operations of the MIPS microarchitecture, such as fetching instructions from the instruction memory, decoding instructions, executing the proper arithmetic operations, reading data from the register file or the data memory, and determining the address of the next instructions. Your simulator will read an executable file (e.g., runme.hex) that contains several instructions (represented in hexadecimal).

The simulator should provide two modes: debug and run mode. In the debug mode, the simulator will show the clock cycles, PC, and register values after executing an instruction every cycle. In the run mode, your simulator will run the given executable file and show the clock cycles, PC, and register values at the end of the simulation.

You can download a zip file (pj2.zip) that includes skeleton code (mips_sim.c) and several executable files (addi_test.hex, add_test.hex, j_test.hex, jal_test.hex, jr_test.hex, beq_test.hex, slti_test.hex, sw_lw_test.hex, and runme.hex) from the project section of the LMS. You can use the skeleton code to write your simulator program. The files named "(*_test.hex)" will be useful for testing your simulator to ensure that it can execute the individual instruction correctly.

Please upload the **"mips_sim.c"** file and a **"README"** file to the LMS system (project section). In the README file, you need to explain your code briefly. **Your program should be able to run on the Linux.**

2. Instruction you must simulate

add, addi, jal, j, jr, lw, sw, slti, beq

3. How to run

./mips_sim ./runme.hex 0 // debug mode

./mips_sim ./runme.hex 1 // run mode

4. Expected output of your simulator

a. Debug mode

* All numbers are decimal number

```
$./mips_sim 0

------------------------------------------------
Clock cycles = 1
PC        = ?

R0  [r0] = 0
R1  [at] = 0
R3  [v0] = ?
R3  [v1] = 0
R4  [a0] = ?
R5  [a1] = 0
R6  [a2] = 0
R7  [a3] = 0
R8  [t0] = ?
R9  [t1] = ?
R10 [t2] = 0
R11 [t3] = 0
R12 [t4] = 0
R13 [t5] = 0
R14 [t6] = 0
R15 [t7] = 0
R16 [s0] = 0
R17 [s1] = 0
R18 [s2] = 0
R19 [s3] = 0
R20 [s4] = 0
R21 [s5] = 0
R22 [s6] = 0
R23 [s7] = 0
```

```
R24 [t8] = 0
R25 [t9] = 0
R26 [k0] = 0
R27 [k1] = 0
R28 [gp] = 0
R29 [sp] = ?
R30 [fp] = 0
R31 [ra] = ?




-------------------------------------------------
Clock cycles = 2
PC       = ?

R0  [r0] = 0
R1  [at] = 0
R3  [v0] = ?
R3  [v1] = 0
R4  [a0] = ?
R5  [a1] = 0
R6  [a2] = 0
R7  [a3] = 0
R8  [t0] = ?
R9  [t1] = ?
R10 [t2] = 0
R11 [t3] = 0
R12 [t4] = 0
R13 [t5] = 0
R14 [t6] = 0
R15 [t7] = 0
R16 [s0] = 0
R17 [s1] = 0
R18 [s2] = 0
R19 [s3] = 0
R20 [s4] = 0
R21 [s5] = 0
R22 [s6] = 0
R23 [s7] = 0
R24 [t8] = 0
R25 [t9] = 0
R26 [k0] = 0
R27 [k1] = 0
R28 [gp] = 0
R29 [sp] = ?
R30 [fp] = 0
R31 [ra] = ?


-------------------------------------------------
Clock cycles = 3
PC       = ?

R0  [r0] = 0
R1  [at] = 0
R3  [v0] = ?
R3  [v1] = 0
R4  [a0] = ?
R5  [a1] = 0
R6  [a2] = 0
R7  [a3] = 0
R8  [t0] = ?
```

```
R9   [t1] = ?
R10 [t2] = 0
R11 [t3] = 0
R12 [t4] = 0
R13 [t5] = 0
R14 [t6] = 0
R15 [t7] = 0
R16 [s0] = 0
R17 [s1] = 0
R18 [s2] = 0
R19 [s3] = 0
R20 [s4] = 0
R21 [s5] = 0
R22 [s6] = 0
R23 [s7] = 0
R24 [t8] = 0
R25 [t9] = 0
R26 [k0] = 0
R27 [k1] = 0
R28 [gp] = 0
R29 [sp] = ?
R30 [fp] = 0
R31 [ra] = ?


..........
```

b. Run mode

* clock cycle is decimal number

```
$./mips_sim 1

Clock cycles = ?
PC       = ?

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 55
R3   [v1] = 0
R4   [a0] = 10
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 1
R9   [t1] = 10
R10 [t2] = 0
R11 [t3] = 0
R12 [t4] = 0
R13 [t5] = 0
R14 [t6] = 0
R15 [t7] = 0
R16 [s0] = 0
R17 [s1] = 0
R18 [s2] = 0
R19 [s3] = 0
R20 [s4] = 0
R21 [s5] = 0
R22 [s6] = 0
```

```
R23 [s7] = 0
R24 [t8] = 0
R25 [t9] = 0
R26 [k0] = 0
R27 [k1] = 0
R28 [gp] = 0
R29 [sp] = 32764
R30 [fp] = 0
R31 [ra] = 12
```

5. Testing

You can find several executable files ("*_test.hex") that you can use to test your simulator.

- Expected output of your simulator for each executable file

  a. addi_test.hex

```
$./mips_sim addi_test.hex 1

Clock cycles = 31
PC        = 124

R0   [r0] = 0
R1   [at] = 10
R2   [v0] = 10
R3   [v1] = 10
R4   [a0] = 10
R5   [a1] = 10
R6   [a2] = 10
R7   [a3] = 10
R8   [t0] = 10
R9   [t1] = 10
R10  [t2] = 10
R11  [t3] = 10
R12  [t4] = 10
R13  [t5] = 10
R14  [t6] = 10
R15  [t7] = 10
R16  [s0] = 10
R17  [s1] = 10
R18  [s2] = 10
R19  [s3] = 10
R20  [s4] = 10
R21  [s5] = 10
R22  [s6] = 10
R23  [s7] = 10
R24  [t8] = 10
R25  [t9] = 10
R26  [k0] = 10
R27  [k1] = 10
R28  [gp] = 10
R29  [sp] = 10
R30  [fp] = 10
R31  [ra] = 10
```

b. add_test.hex

```
$./mips_sim add_test.hex 1

Clock cycles = 4
PC       = 16

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 0
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 10
R17  [s1] = 20
R18  [s2] = 30
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 0
R30  [fp] = 0
R31  [ra] = 0
```

c. jal_test.hex

```
$./mips_sim jal_test.hex 1

Clock cycles = 3
PC      = 16

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 0
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 0
R17  [s1] = 20
R18  [s2] = 0
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 0
R30  [fp] = 0
R31  [ra] = 4
```

d. j_test.hex

```
$./mips_sim j_test.hex 1

Clock cycles = 3
PC      = 16

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 0
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 0
R17  [s1] = 20
R18  [s2] = 0
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 0
R30  [fp] = 0
R31  [ra] = 0
```

e. jr_test.hex

```
$./mips_sim jr_test.hex 1

Clock cycles = 3
PC      = 20

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 0
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 0
R17  [s1] = 0
R18  [s2] = 0
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 0
R30  [fp] = 0
R31  [ra] = 16
```

f. sw_lw_test.hex

```
$./mips_sim sw_lw_test.hex 1

Clock cycles = 5
PC       = 20

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 30
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 30
R17  [s1] = 0
R18  [s2] = 0
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 32764
R30  [fp] = 0
R31  [ra] = 0
```

g. slti_test.hex

```
$./mips_sim slti_test.hex 1

Clock cycles = 4
PC      = 16

R0    [r0] = 0
R1    [at] = 0
R2    [v0] = 0
R3    [v1] = 0
R4    [a0] = 0
R5    [a1] = 0
R6    [a2] = 0
R7    [a3] = 0
R8    [t0] = 0
R9    [t1] = 10
R10   [t2] = 0
R11   [t3] = 0
R12   [t4] = 0
R13   [t5] = 0
R14   [t6] = 0
R15   [t7] = 0
R16   [s0] = 10
R17   [s1] = 0
R18   [s2] = 1
R19   [s3] = 0
R20   [s4] = 0
R21   [s5] = 0
R22   [s6] = 0
R23   [s7] = 0
R24   [t8] = 0
R25   [t9] = 0
R26   [k0] = 0
R27   [k1] = 0
R28   [gp] = 0
R29   [sp] = 0
R30   [fp] = 0
R31   [ra] = 0
```

h. beq_test.hex

```
$./mips_sim beq_test.hex 1

Clock cycles = 4
PC      = 20

R0   [r0] = 0
R1   [at] = 0
R2   [v0] = 0
R3   [v1] = 0
R4   [a0] = 0
R5   [a1] = 0
R6   [a2] = 0
R7   [a3] = 0
R8   [t0] = 0
R9   [t1] = 10
R10  [t2] = 0
R11  [t3] = 0
R12  [t4] = 0
R13  [t5] = 0
R14  [t6] = 0
R15  [t7] = 0
R16  [s0] = 30
R17  [s1] = 30
R18  [s2] = 0
R19  [s3] = 0
R20  [s4] = 0
R21  [s5] = 0
R22  [s6] = 0
R23  [s7] = 0
R24  [t8] = 0
R25  [t9] = 0
R26  [k0] = 0
R27  [k1] = 0
R28  [gp] = 0
R29  [sp] = 0
R30  [fp] = 0
R31  [ra] = 0
```

6. **Evaluation** [total: 100 points]

    a. **Unit test** [45 points] **:** test your simulator to ensure that it can execute individual instruction (add, addi, jal, j, jr, lw, sw, slti, beq) correctly.

    b. **Full test** [55 points] **:** test your simulator to ensure that it can correctly execute the given executable file. We will use the "runme.hex" file for the full test.

Late Day Policy

All homeworks are due at 11:59pm on the due date. A grading penalty will be applied to late assignments. Any assignment turned in late will be penalized 25% per late day.

Plagiarism

No plagiarism will be tolerated. If the instructor determines that there are substantial similarities between your code and others, you will be given 0 points for all project assignments. Code similarity will be checked with a plagiarism detector tool.