Assignment 1

Haiyu Wang

1. Configuration File:

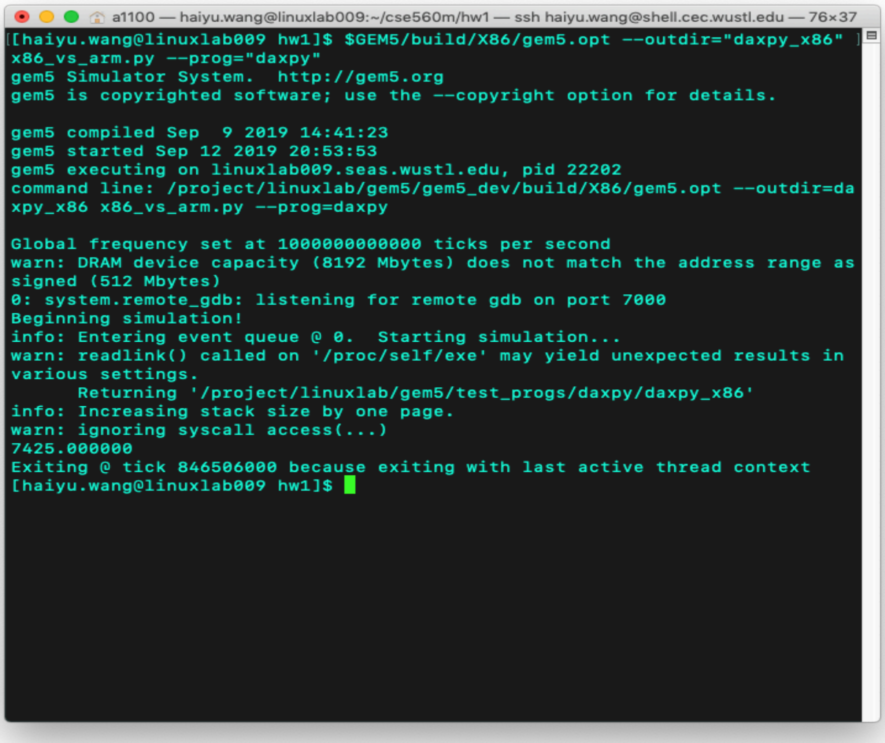
   x86_vs_arm.py

```
# Assignment 1, Haiyu Wang
# Usage: like $GEM5/build/X86/gem5.opt --outdir="daxpy_x86"
#                              x86_vs_arm.py --prog="daxpy"
#
# Set up simulator with GEM5, run programs and test them

import m5
from m5.objects import *

import os
gem5_path = os.environ["GEM5"]

#option parser and specify the program
import optparse
parser = optparse.OptionParser()
parser.add_option("--prog", type="str", default=None);
(options, args) = parser.parse_args()
program = options.prog

system = System() #instantiate system

system.clk_domain = SrcClockDomain() #set clock domain

system.clk_domain.voltage_domain = VoltageDomain() #set voltage domain

# set clock condition
isa = m5.defines.buildEnv['TARGET_ISA']
if isa == "x86":
  system.clk_domain.clock = '1GHz'
elif isa == "arm":
  system.clk_domain.clock = '1.2GHz'

# use timing mode and set memory range
system.mem_mode = 'timing'
system.mem_ranges = [AddrRange('512MB')]

#set cpu and membus
system.cpu = TimingSimpleCPU()
system.membus = SystemXBar()

# set cache
system.cpu.icache_port = system.membus.slave
system.cpu.dcache_port = system.membus.slave

# connect PIO and interrupts ports to membus
system.cpu.createInterruptController()
if isa == 'x86':
  system.cpu.interrupts[0].pio = system.membus.master
  system.cpu.interrupts[0].int_master = system.membus.slave
  system.cpu.interrupts[0].int_slave = system.membus.master

system.system_port = system.membus.slave

# set memory controller
system.mem_ctrl = DDR3_1600_8x8()
system.mem_ctrl.range = system.mem_ranges[0]
system.mem_ctrl.port = system.membus.master

# set up process
process = Process()
apps_path = "/project/linuxlab/gem5/test_progs"
```

```
if program == "daxpy" and isa == "x86":

  process.cmd = [apps_path + '/daxpy/daxpy_x86']

elif program == "daxpy" and isa == "arm":

  process.cmd = [apps_path + '/daxpy/daxpy_arm']

elif program == "queens" and isa == "x86":

  process.cmd = [apps_path + '/queens/queens_x86']

  process.cmd += ["10 -c"]

elif program == "queens" and isa == "arm":

  process.cmd = [apps_path + '/queens/queens_arm']

  process.cmd += ["10 -c"]


system.cpu.workload = process

system.cpu.createThreads()


# create root object

root = Root(full_system = False, system = system)

m5.instantiate()

print ("Beginning simulation!")


exit_event = m5.simulate()

print('Exiting @ tick %i because %s' % (m5.curTick(),

exit_event.getCause()))
```

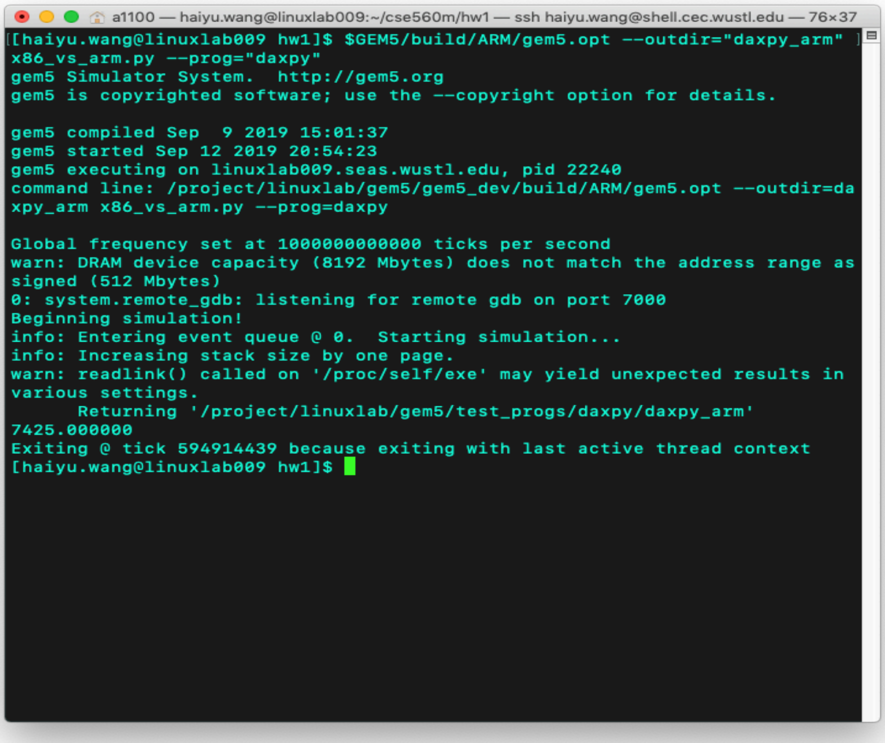
2. Outputs

a) Program: daxpy_x86


a1100 — haiyu.wang@linuxlab009:~/cse560m/hw1 — ssh haiyu.wang@shell.cec.wustl.edu — 76×37

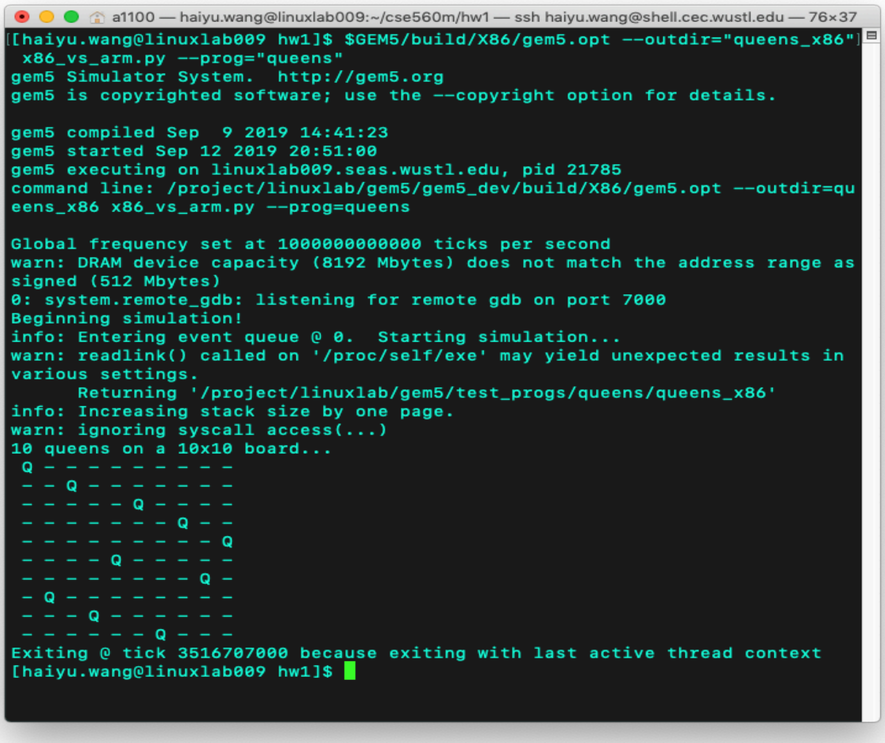
```
[haiyu.wang@linuxlab009 hw1]$ $GEM5/build/X86/gem5.opt --outdir="daxpy_x86"
x86_vs_arm.py --prog="daxpy"
gem5 Simulator System.  http://gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 compiled Sep  9 2019 14:41:23
gem5 started Sep 12 2019 20:53:53
gem5 executing on linuxlab009.seas.wustl.edu, pid 22202
command line: /project/linuxlab/gem5/gem5_dev/build/X86/gem5.opt --outdir=da
xpy_x86 x86_vs_arm.py --prog=daxpy

Global frequency set at 1000000000000 ticks per second
warn: DRAM device capacity (8192 Mbytes) does not match the address range as
signed (512 Mbytes)
0: system.remote_gdb: listening for remote gdb on port 7000
Beginning simulation!
info: Entering event queue @ 0.  Starting simulation...
warn: readlink() called on '/proc/self/exe' may yield unexpected results in
various settings.
      Returning '/project/linuxlab/gem5/test_progs/daxpy/daxpy_x86'
info: Increasing stack size by one page.
warn: ignoring syscall access(...)
7425.000000
Exiting @ tick 846506000 because exiting with last active thread context
[haiyu.wang@linuxlab009 hw1]$ 
```

b) Program: daxpy_arm


a1100 — haiyu.wang@linuxlab009:~/cse560m/hw1 — ssh haiyu.wang@shell.cec.wustl.edu — 76×37

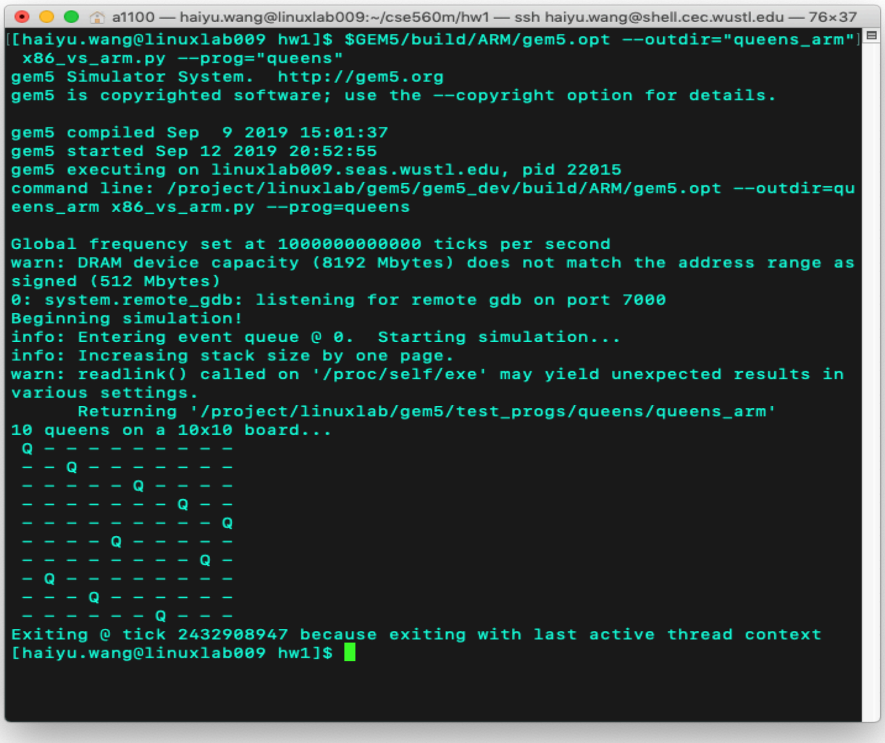
```
[haiyu.wang@linuxlab009 hw1]$ $GEM5/build/ARM/gem5.opt --outdir="daxpy_arm"
x86_vs_arm.py --prog="daxpy"
gem5 Simulator System.  http://gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 compiled Sep  9 2019 15:01:37
gem5 started Sep 12 2019 20:54:23
gem5 executing on linuxlab009.seas.wustl.edu, pid 22240
command line: /project/linuxlab/gem5/gem5_dev/build/ARM/gem5.opt --outdir=da
xpy_arm x86_vs_arm.py --prog=daxpy

Global frequency set at 1000000000000 ticks per second
warn: DRAM device capacity (8192 Mbytes) does not match the address range as
signed (512 Mbytes)
0: system.remote_gdb: listening for remote gdb on port 7000
Beginning simulation!
info: Entering event queue @ 0.  Starting simulation...
info: Increasing stack size by one page.
warn: readlink() called on '/proc/self/exe' may yield unexpected results in
various settings.
      Returning '/project/linuxlab/gem5/test_progs/daxpy/daxpy_arm'
7425.000000
Exiting @ tick 594914439 because exiting with last active thread context
[haiyu.wang@linuxlab009 hw1]$ 
```

c) Program: queens_x86


a1100 — haiyu.wang@linuxlab009:~/cse560m/hw1 — ssh haiyu.wang@shell.cec.wustl.edu — 76×37

```
[haiyu.wang@linuxlab009 hw1]$ $GEM5/build/X86/gem5.opt --outdir="queens_x86"]
 x86_vs_arm.py --prog="queens"
gem5 Simulator System.  http://gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 compiled Sep  9 2019 14:41:23
gem5 started Sep 12 2019 20:51:00
gem5 executing on linuxlab009.seas.wustl.edu, pid 21785
command line: /project/linuxlab/gem5/gem5_dev/build/X86/gem5.opt --outdir=qu
eens_x86 x86_vs_arm.py --prog=queens

Global frequency set at 1000000000000 ticks per second
warn: DRAM device capacity (8192 Mbytes) does not match the address range as
signed (512 Mbytes)
0: system.remote_gdb: listening for remote gdb on port 7000
Beginning simulation!
info: Entering event queue @ 0.  Starting simulation...
warn: readlink() called on '/proc/self/exe' may yield unexpected results in
various settings.
      Returning '/project/linuxlab/gem5/test_progs/queens/queens_x86'
info: Increasing stack size by one page.
warn: ignoring syscall access(...)
10 queens on a 10x10 board...
 Q - - - - - - - - -
 - - Q - - - - - - -
 - - - - - Q - - - -
 - - - - - - - Q - -
 - - - - - - - - - Q
 - - - - Q - - - - -
 - - - - - - - - Q -
 - Q - - - - - - - -
 - - - Q - - - - - -
 - - - - - - Q - - -
Exiting @ tick 3516707000 because exiting with last active thread context
[haiyu.wang@linuxlab009 hw1]$ 
```

d) Program: queens_arm


a1100 — haiyu.wang@linuxlab009:~/cse560m/hw1 — ssh haiyu.wang@shell.cec.wustl.edu — 76×37

```
[haiyu.wang@linuxlab009 hw1]$ $GEM5/build/ARM/gem5.opt --outdir="queens_arm"]
 x86_vs_arm.py --prog="queens"
gem5 Simulator System.  http://gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 compiled Sep  9 2019 15:01:37
gem5 started Sep 12 2019 20:52:55
gem5 executing on linuxlab009.seas.wustl.edu, pid 22015
command line: /project/linuxlab/gem5/gem5_dev/build/ARM/gem5.opt --outdir=qu
eens_arm x86_vs_arm.py --prog=queens

Global frequency set at 1000000000000 ticks per second
warn: DRAM device capacity (8192 Mbytes) does not match the address range as
signed (512 Mbytes)
0: system.remote_gdb: listening for remote gdb on port 7000
Beginning simulation!
info: Entering event queue @ 0.  Starting simulation...
info: Increasing stack size by one page.
warn: readlink() called on '/proc/self/exe' may yield unexpected results in
various settings.
      Returning '/project/linuxlab/gem5/test_progs/queens/queens_arm'
10 queens on a 10x10 board...
 Q - - - - - - - - -
 - - Q - - - - - - -
 - - - - - Q - - - -
 - - - - - - - Q - -
 - - - - - - - - - Q
 - - - - Q - - - - -
 - - - - - - - - Q -
 - Q - - - - - - - -
 - - - Q - - - - - -
 - - - - - - Q - - -
Exiting @ tick 2432908947 because exiting with last active thread context
[haiyu.wang@linuxlab009 hw1]$ 
```

3. Response

a) Confirmation of the execution time

i. Program daxpy_x86

sim_seconds	0.000847
Number of instructions	10233 (sim_insts)
Clock cycles	846506 (system.cpu.numCycles)
CPI	846505/10233 = 82.72
t_{clk}	1000/1000000000000 = 0.000000001 (system.clk_domain.clock/sim_freq)

$t_{execution\_time}$ = (number of instructions) × CPI × t_{clk}

= 10233×82.72×0.000000001 ≈ 0.000847

ii. Program daxpy_arm

sim_seconds	0.000595
Number of instructions	9361
Clock cycles	714183
CPI	714183/9361 = 76.29
t_{clk}	833/1000000000000 = 0.000000000833

$t_{execution\_time}$ = (number of instructions) × CPI × t_{clk}

= 9361×76.29×0.000000000833 ≈ 0.000595

iii. Program queens_x86

sim_seconds	0.003517
Number of instructions	41261
Clock cycles	3516707
CPI	3516707/41261 = 85.23
t_{clk}	1000/1000000000000 = 0.000000001

$t_{execution\_time}$ = (number of instructions) × CPI × t_{clk}

= 41261×85.23×0.000000001 ≈ 0.003517

iv. Program queens_arm

sim_seconds	0.002433
Number of instructions	37778
Clock cycles	2920659
CPI	2920659/37778 = 77.31
t_{clk}	833/1000000000000 = 0.000000000833

$t_{execution\_time}$ = (number of instructions) × CPI × t_{clk}

= 37778×77.31×0.000000000833 ≈ 0.002433

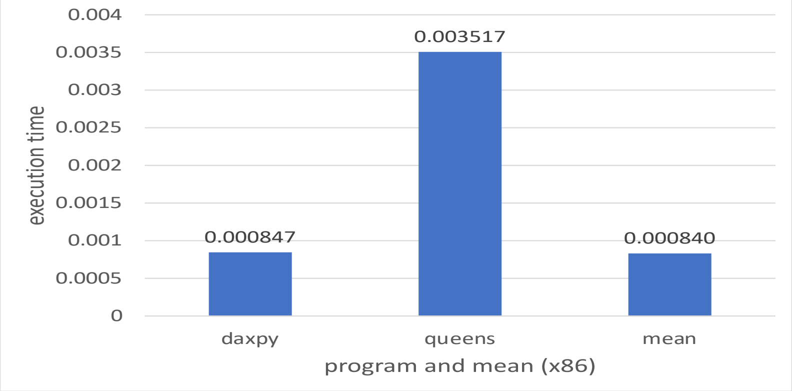
With the calculation above, all of the sim_seconds are the same as the $t_{execution\_time}$, so we can confirm the execution time are sim_seconds.

b) Plots

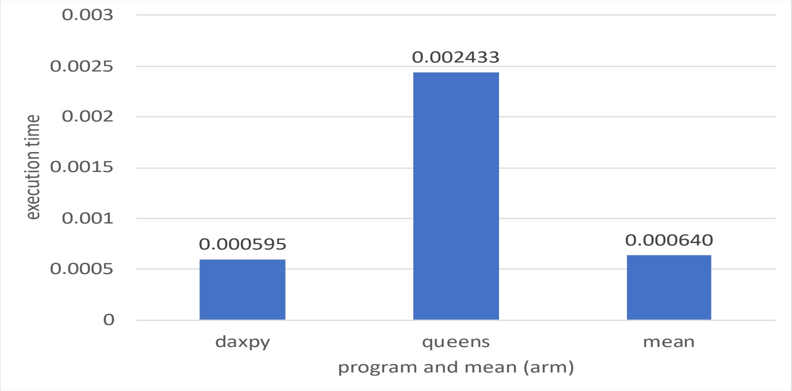
Note: mean is the average time of executing 10000 instructions.

$$mean = \frac{1}{2} \times \left(\frac{daxpy\_time}{daxpy\_insts\_number} + \frac{queens\_time}{queens\_insts\_number}\right) \times 10000$$

i. Plot: x86 execution time



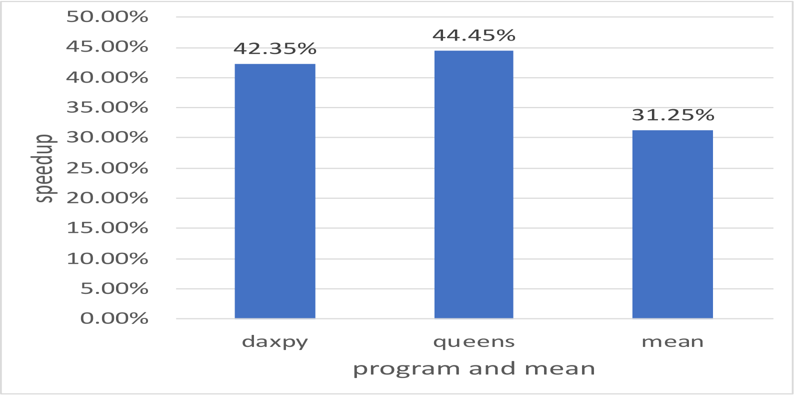
ii. Plot: arm execution time



iii. Plot: speedup

Since the execution time of ARM ISA is shorter than that of x86 ISA, ARM ISA is faster.

	Speedup
daxpy	(1/0.000595 – 1/0.000847) ÷ (1/0.000847) × 100% = 42.35%
queens	(1/0.002433 – 1/0.003517) ÷ (1/0.003517) × 100% = 44.55%
mean	(1/0.000640 – 1/0.000840) ÷ (1/0.000840) × 100% = 31.25%


speedup
daxpy
queens
mean
program and mean